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US005491760A

United States Patent [19][11] **Patent Number:** 5,491,760

Withgott et al.

[45] **Date of Patent:** Feb. 13, 1996[54] **METHOD AND APPARATUS FOR SUMMARIZING A DOCUMENT WITHOUT DOCUMENT IMAGE DECODING**

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Todd A. Cass, Cambridge, Mass.;
Ronald M. Kaplan, Palo Alto;
Ramana R. Rao, San Francisco, both
 of Calif.

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Primary Examiner—Leo Boudreau

Assistant Examiner—Phuoc Tran

Attorney, Agent, or Firm—Oliff & Berridge

[73] Assignee: **Xerox Corporation**, Stamford, Conn.

[21] Appl. No.: **240,284**

[22] Filed: **May 9, 1994**

Related U.S. Application Data

[63] Continuation of Ser. No. 794,543, Nov. 19, 1991, abandoned.

[51] Int. Cl.⁶ **G06K 9/46**

[52] U.S. Cl. **382/203; 382/177; 382/229**

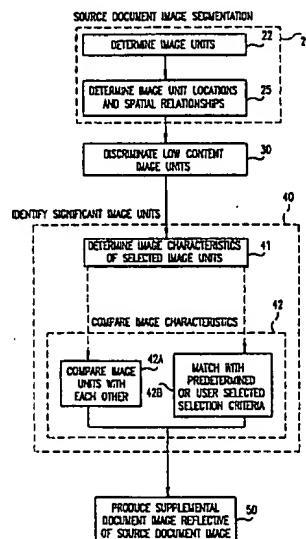
[58] Field of Search **382/9, 55, 1, 28,**
382/30, 25, 40, 177, 190, 114, 198, 199,
200, 203, 209, 206, 229, 257, 308; 364/419.03,
419.19

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[57] **ABSTRACT**

A method and apparatus for excerpting and summarizing an undecoded document image, without first converting the document image to optical character codes such as ASCII text, identifies significant words, phrases and graphics in the document image using automatic or interactive morphological image recognition techniques, document summaries or indices are produced based on the identified significant portions of the document image. The disclosed method is particularly adept for improvement of reading machines for the blind.

20 Claims, 39 Drawing Sheets

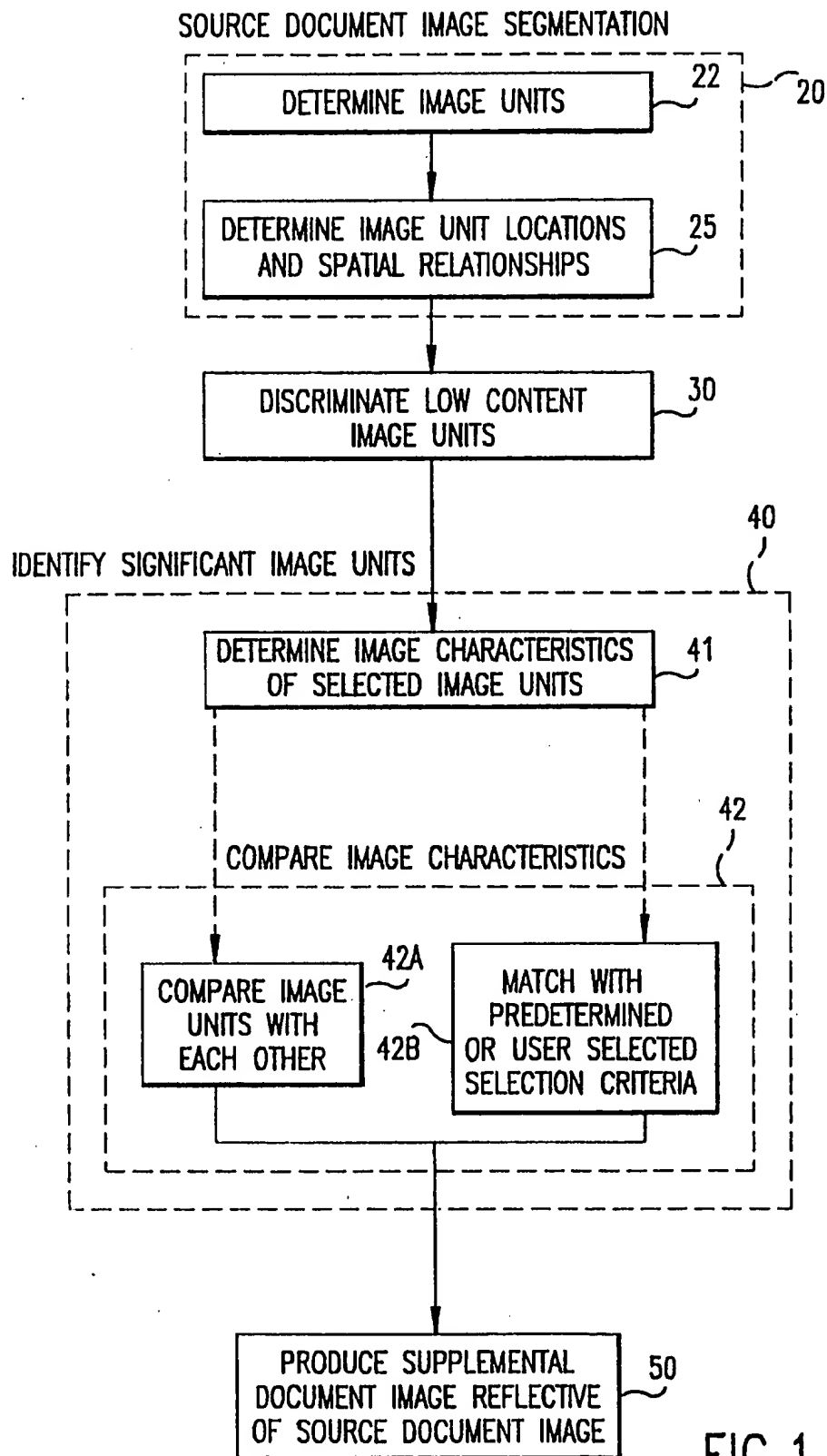


FIG. 1

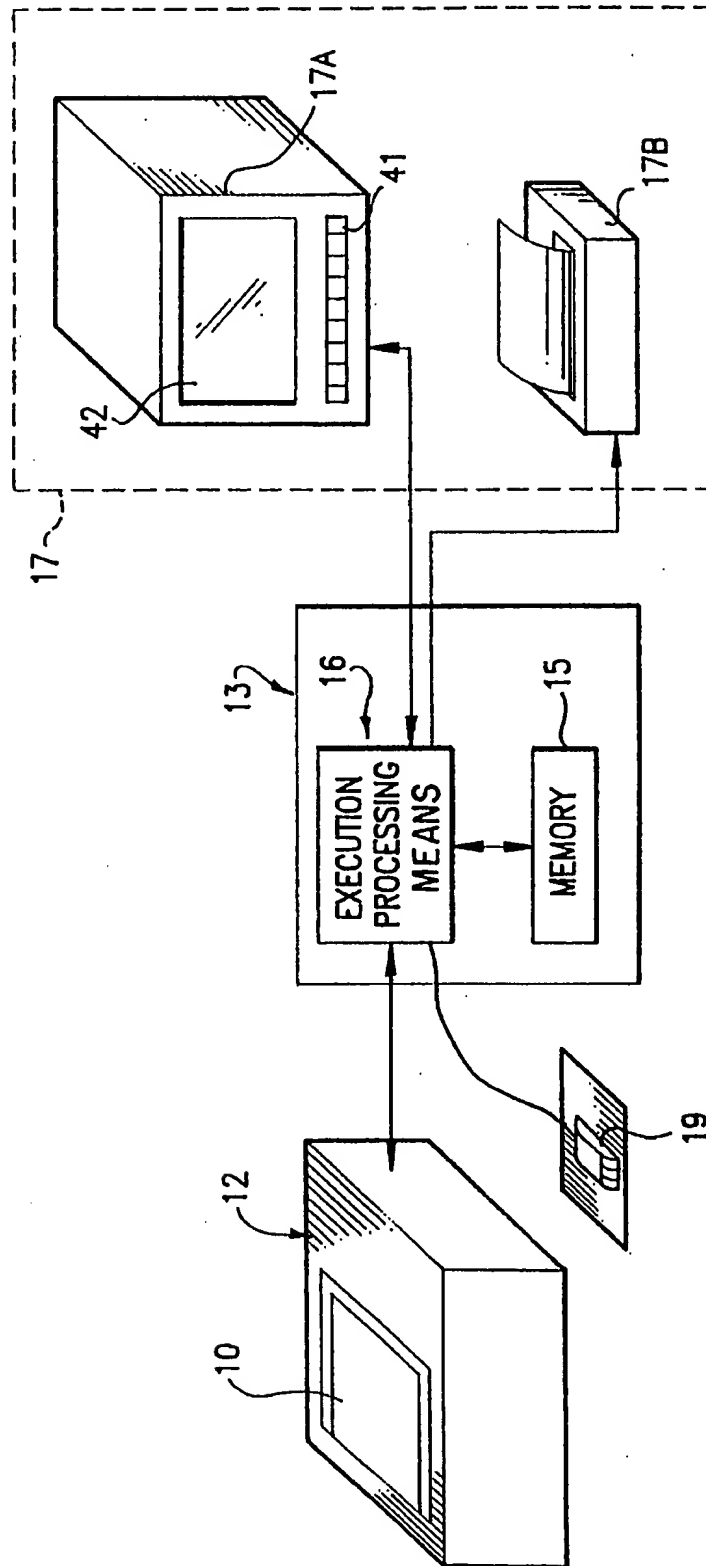


FIG. 2

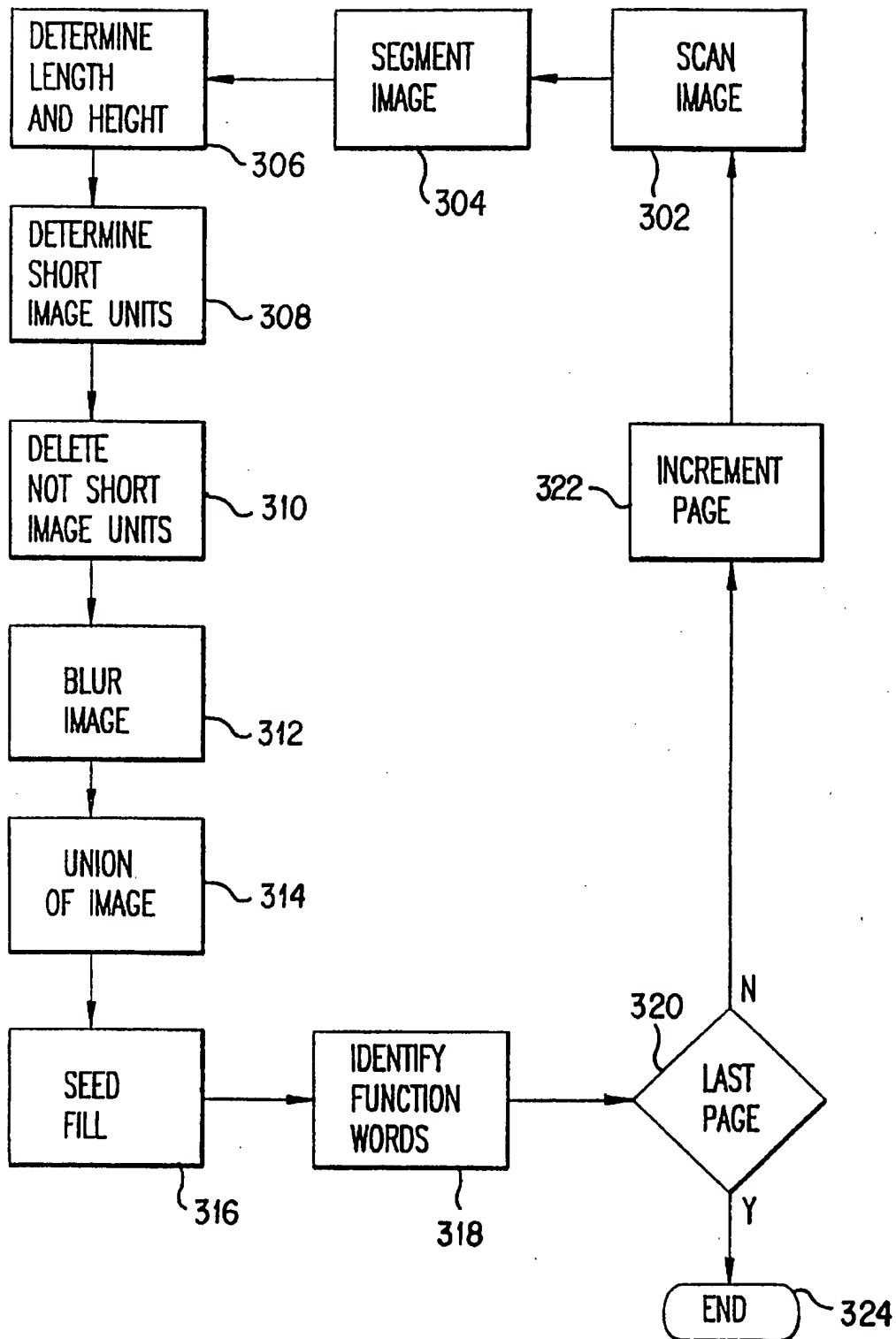


FIG. 3

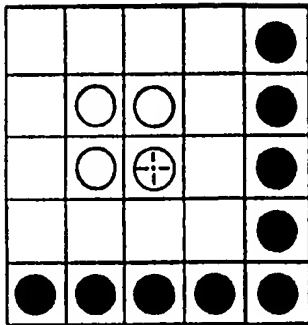


FIG. 4E

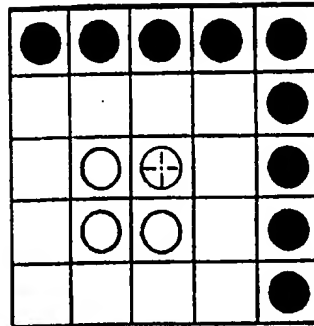


FIG. 4F

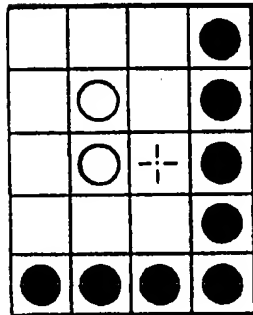


FIG. 4C

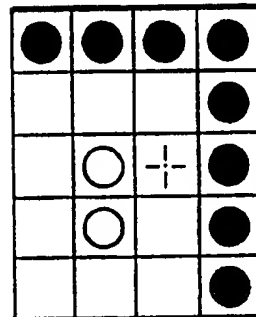


FIG. 4D

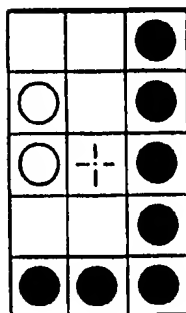


FIG. 4A

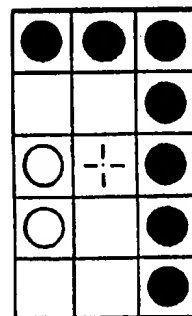


FIG. 4B

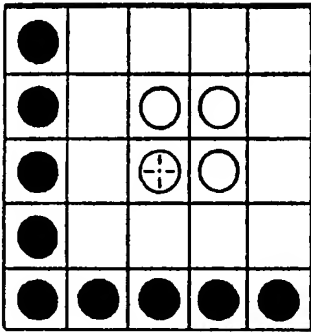


FIG. 5E

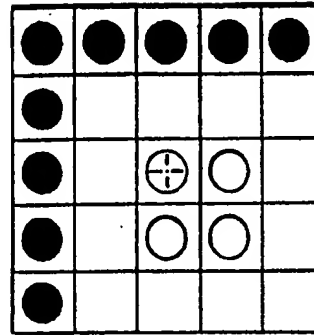


FIG. 5F

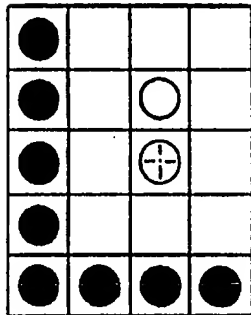


FIG. 5C

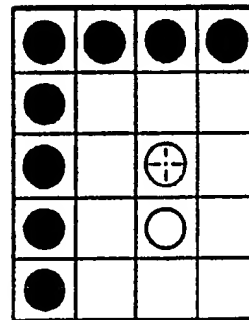


FIG. 5D

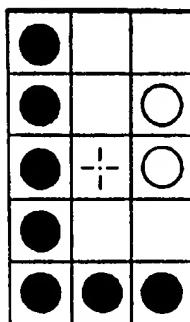


FIG. 5A

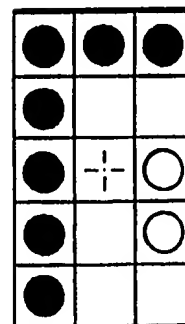


FIG. 5B

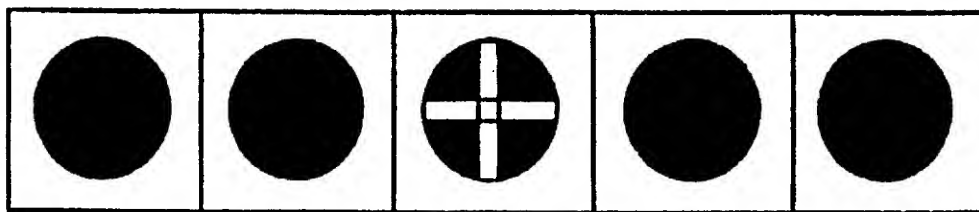
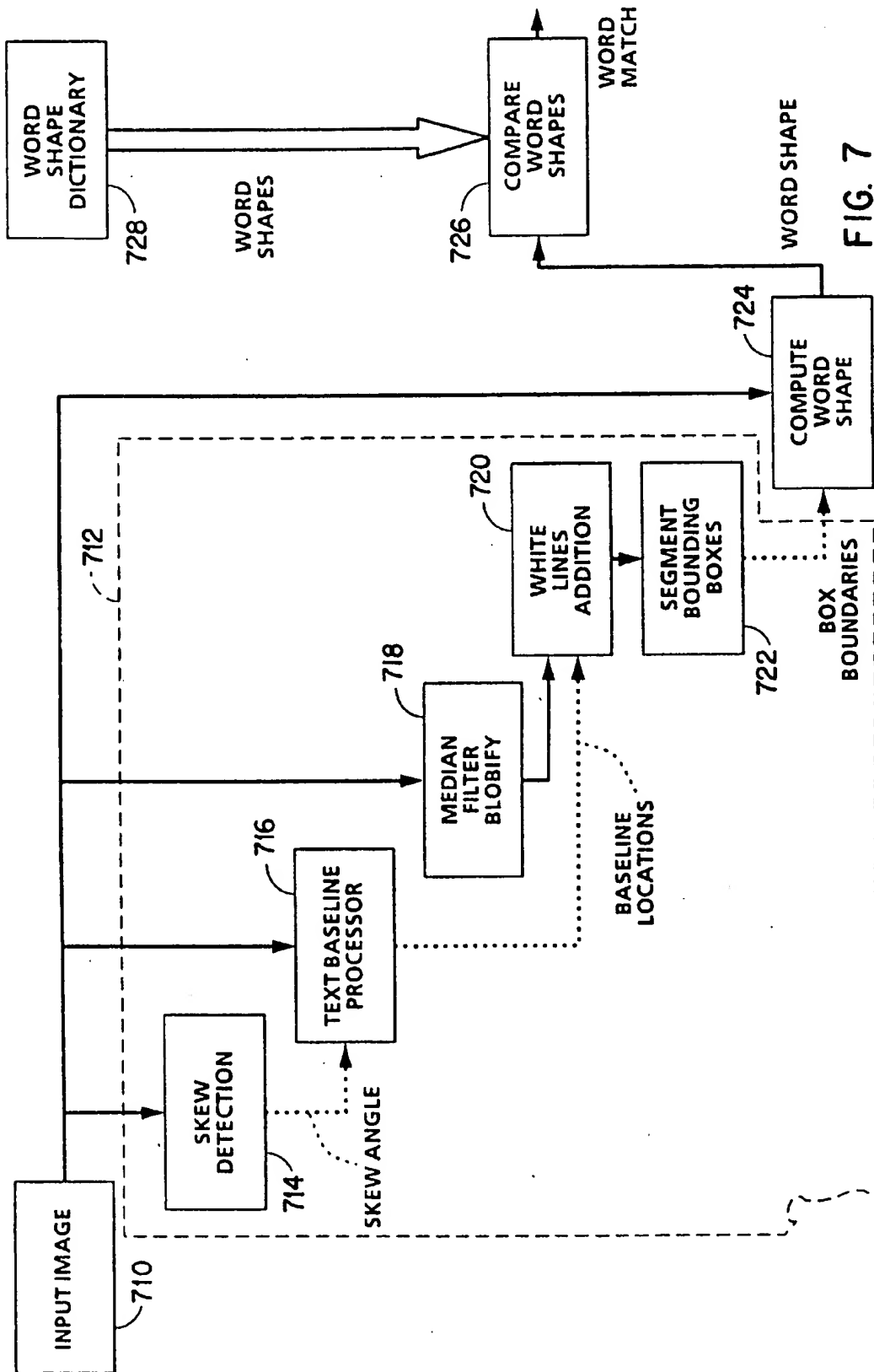
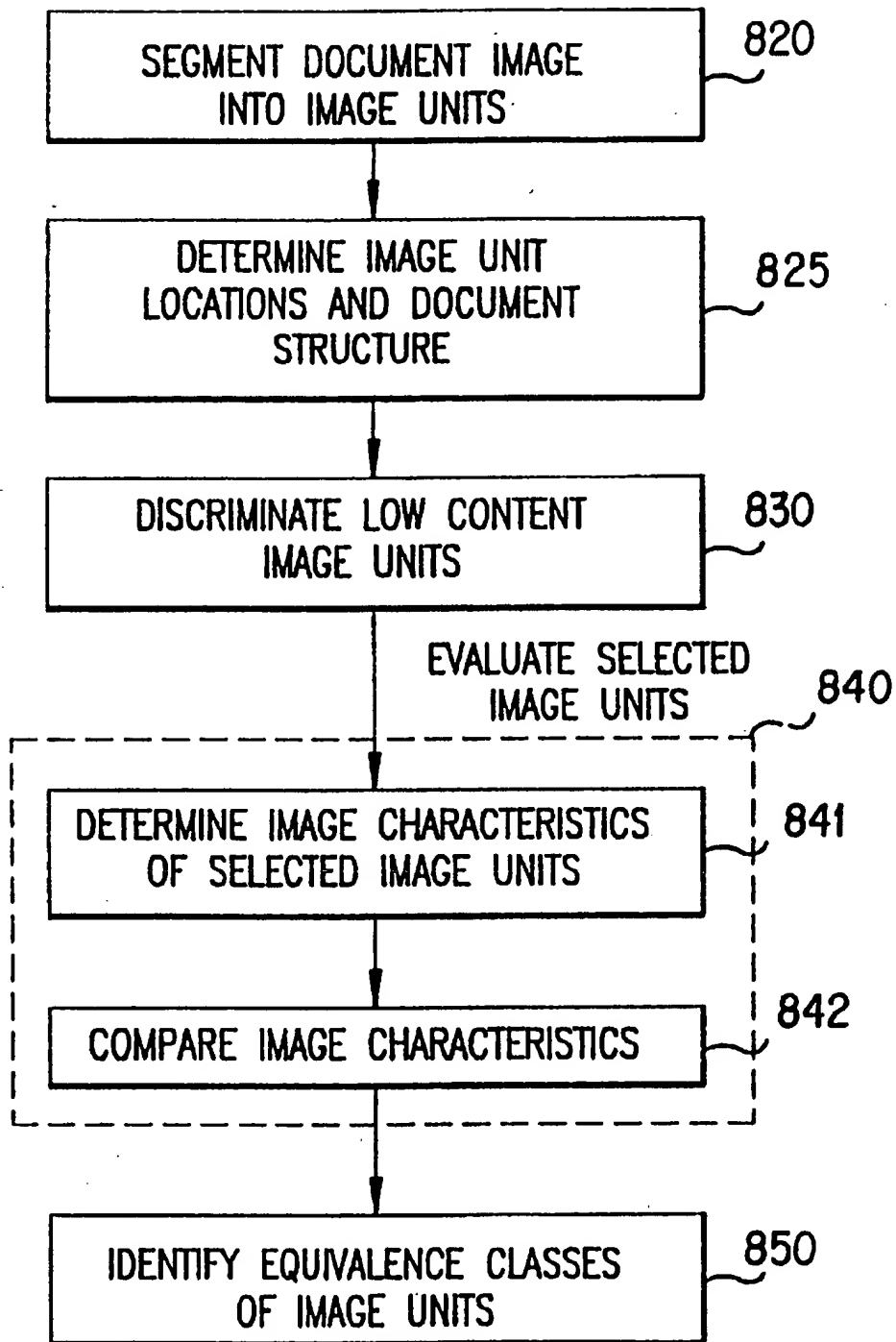


FIG. 6



**FIG. 8**

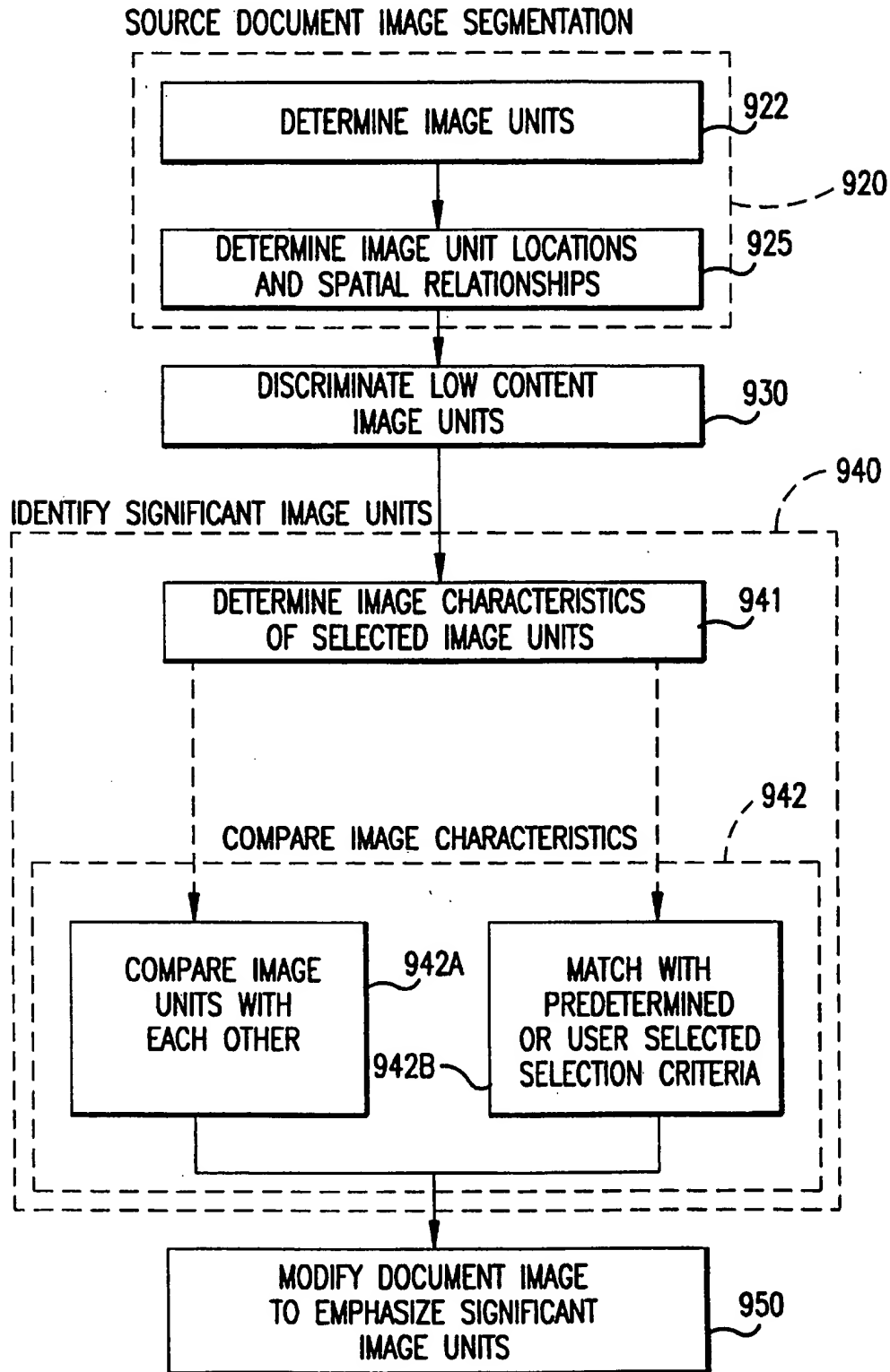


FIG.9

A practitioner may not solicit professional employment from a prospective client with whom the practitioner has no family or prior professional relationship, by mail, in-person or otherwise, when a significant motive for the practitioner's doing so is the practitioner's pecuniary gain under circumstances evidencing undue influence, in-

FIG. 10

A practitioner may not solicit professional employment from a prospective client with whom the practitioner has no family or prior professional relationship, by mail, in-person or otherwise, when a significant motive for the practitioner's doing so is the practitioner's pecuniary gain under circumstances evidencing undue influence, in-

50a

54

52

FIG. 11

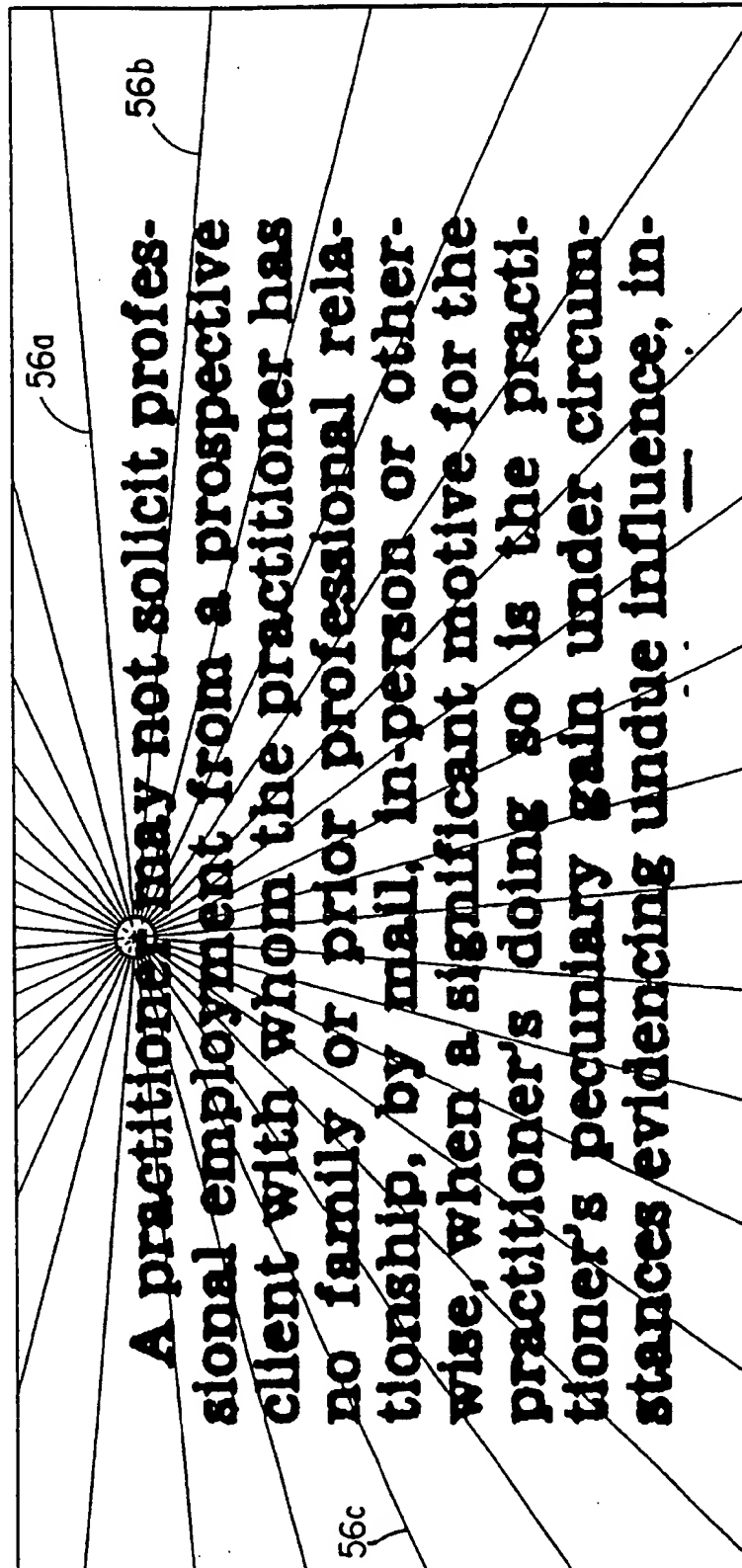


FIG. 12A

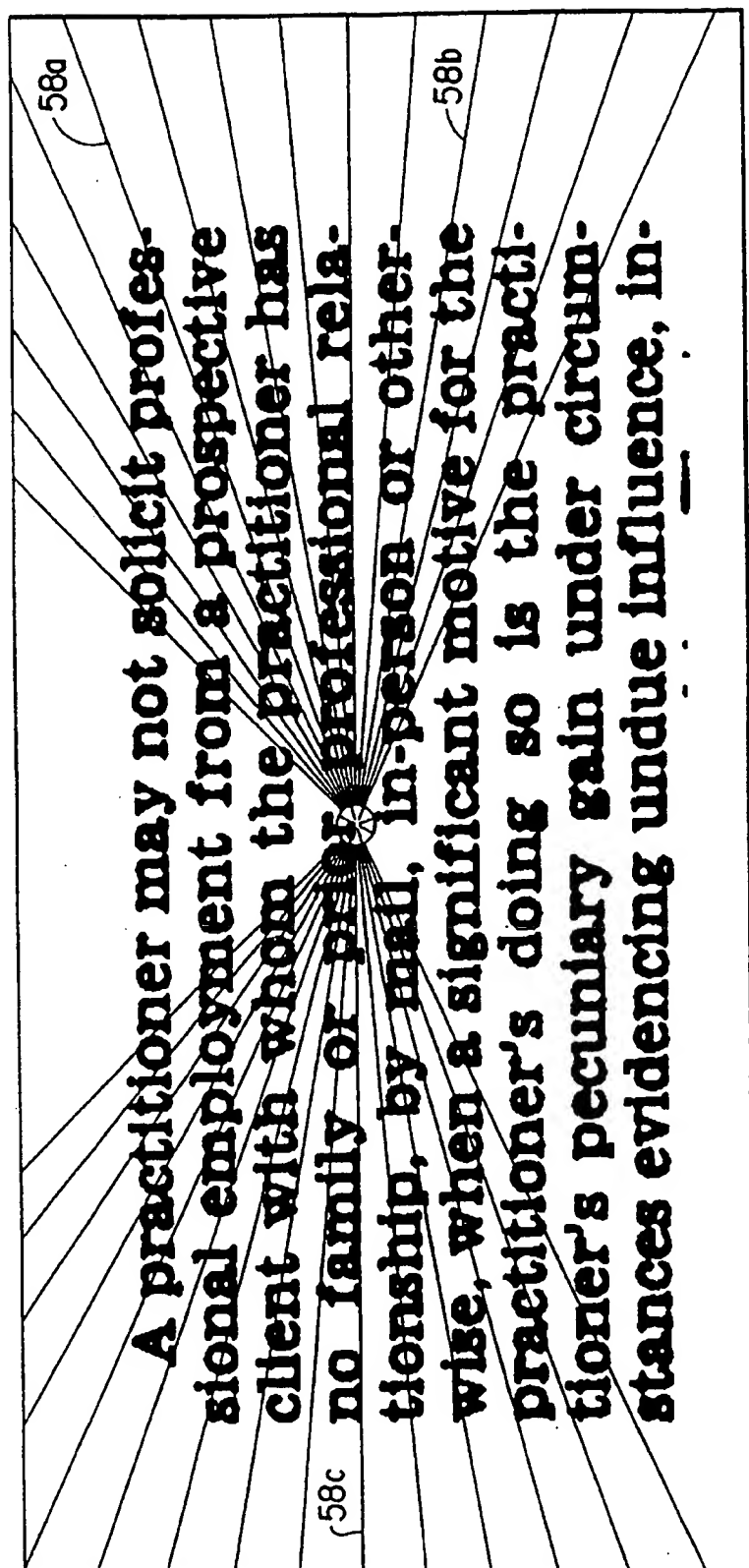


FIG. 12B

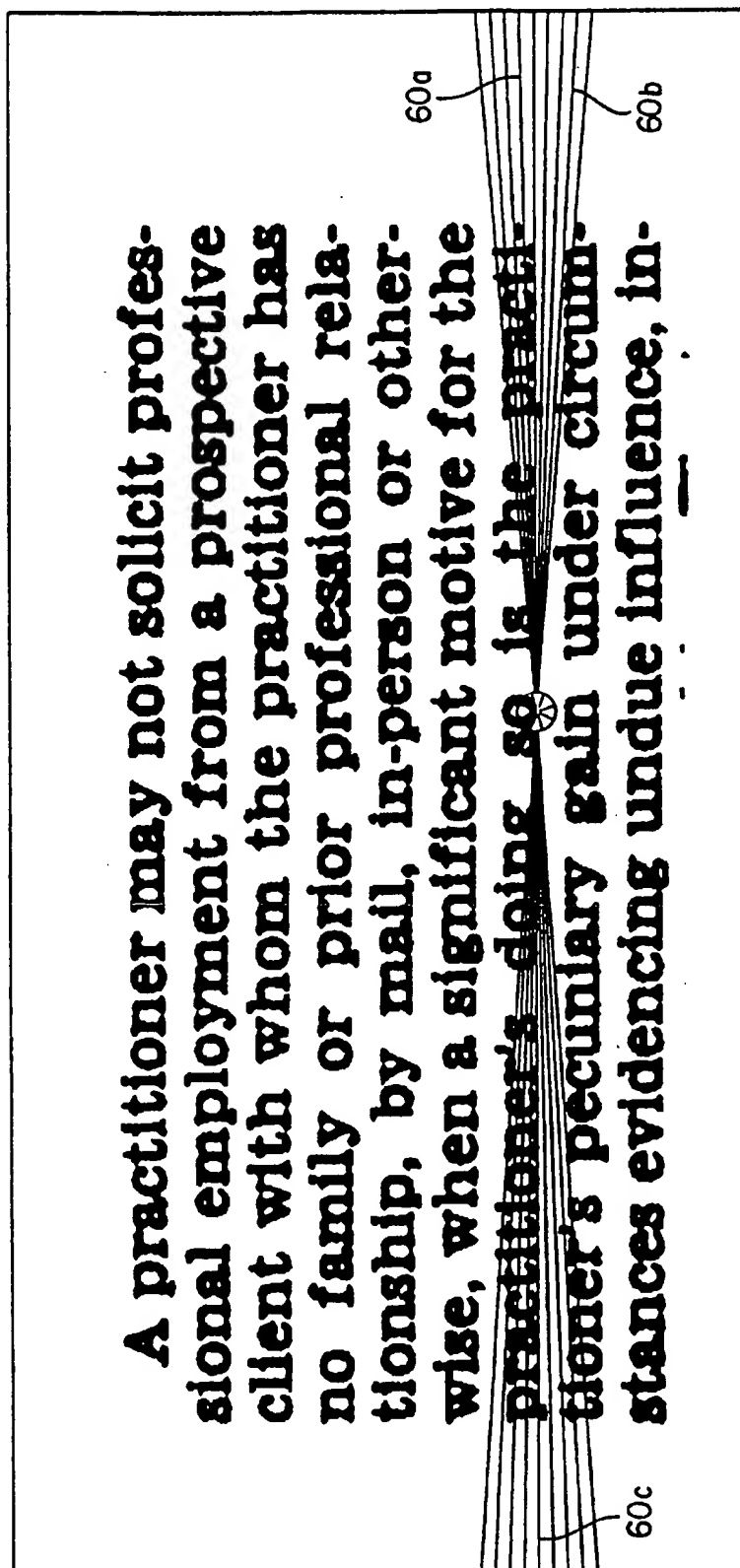


FIG. 12C

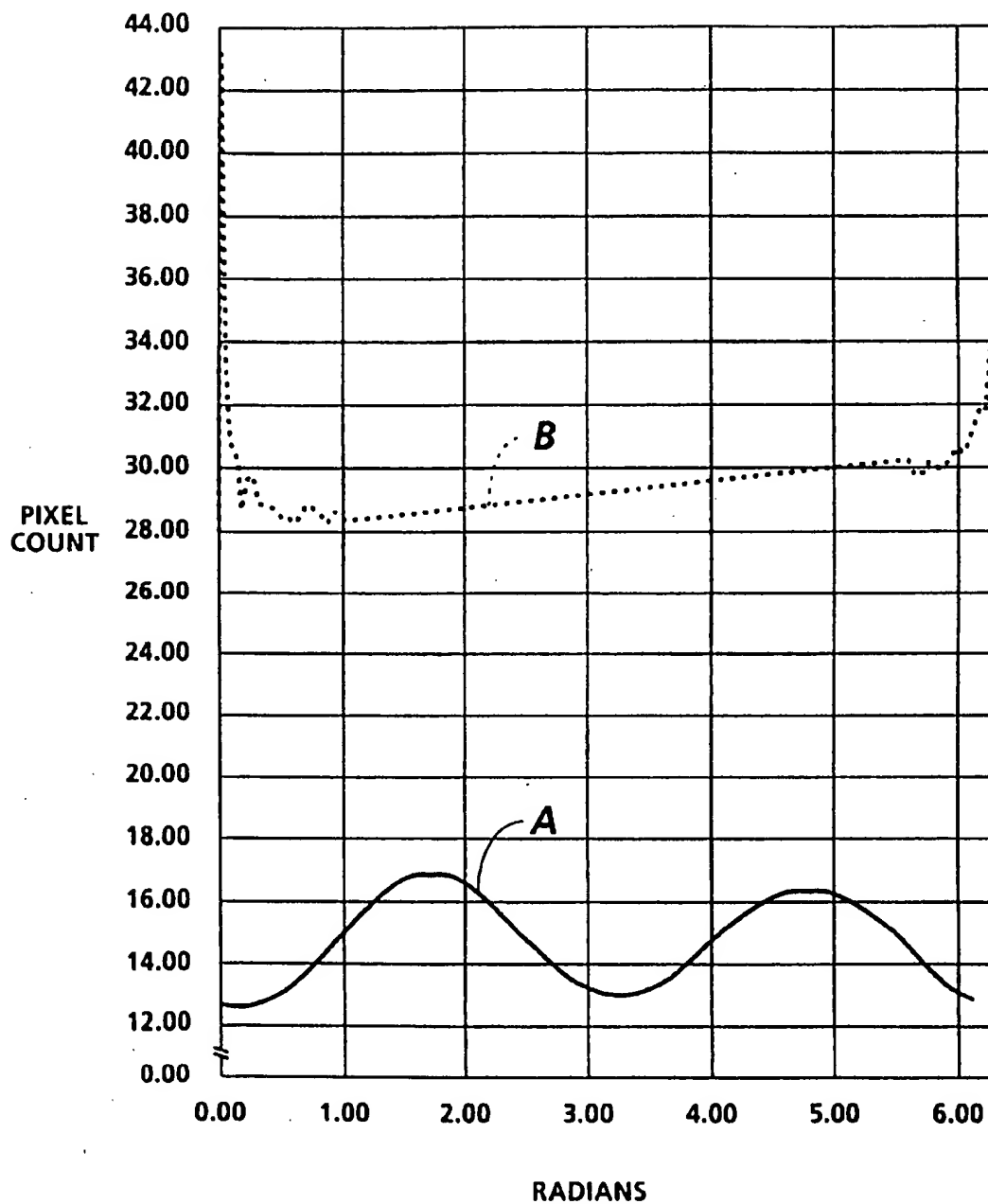


FIG. 12D

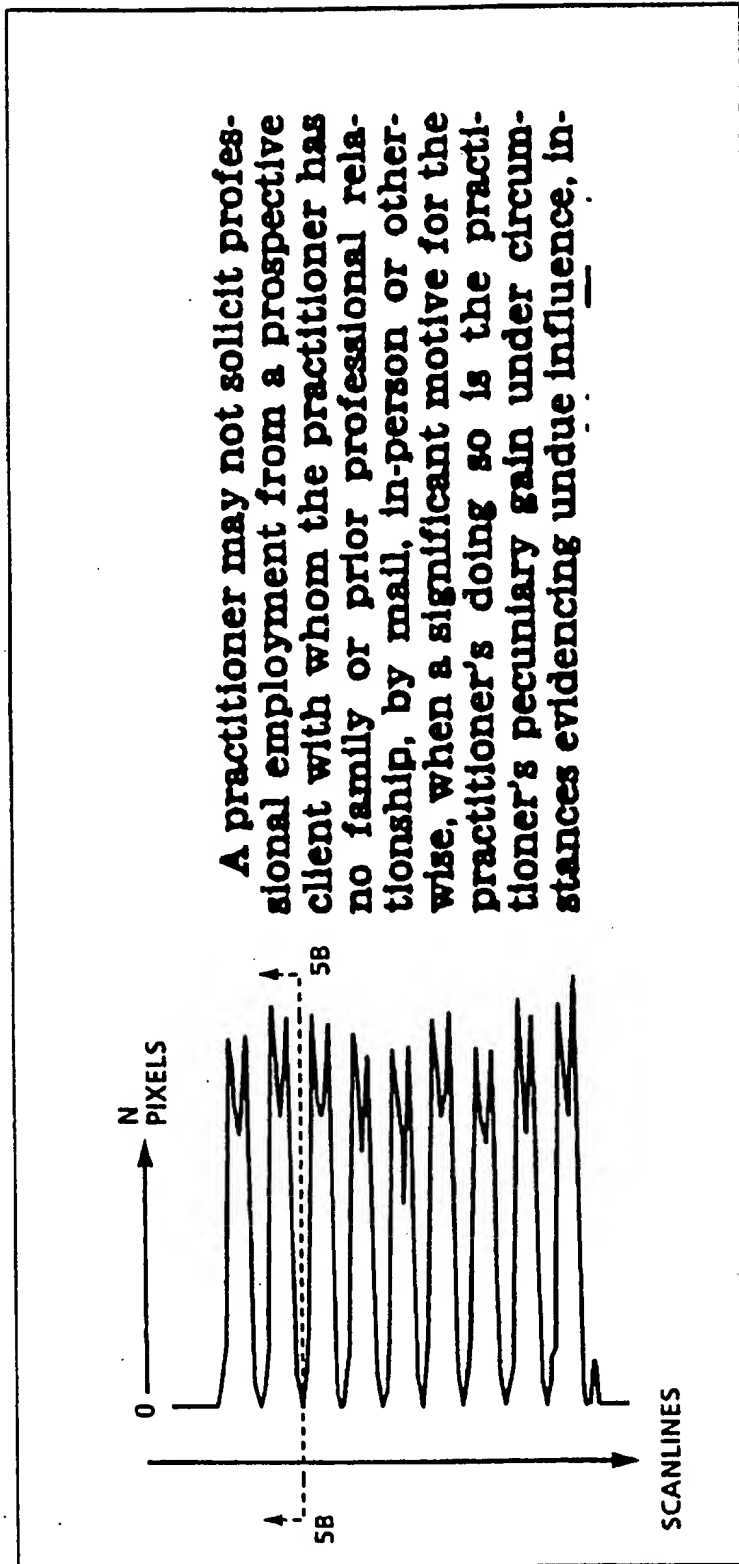


FIG. 13A

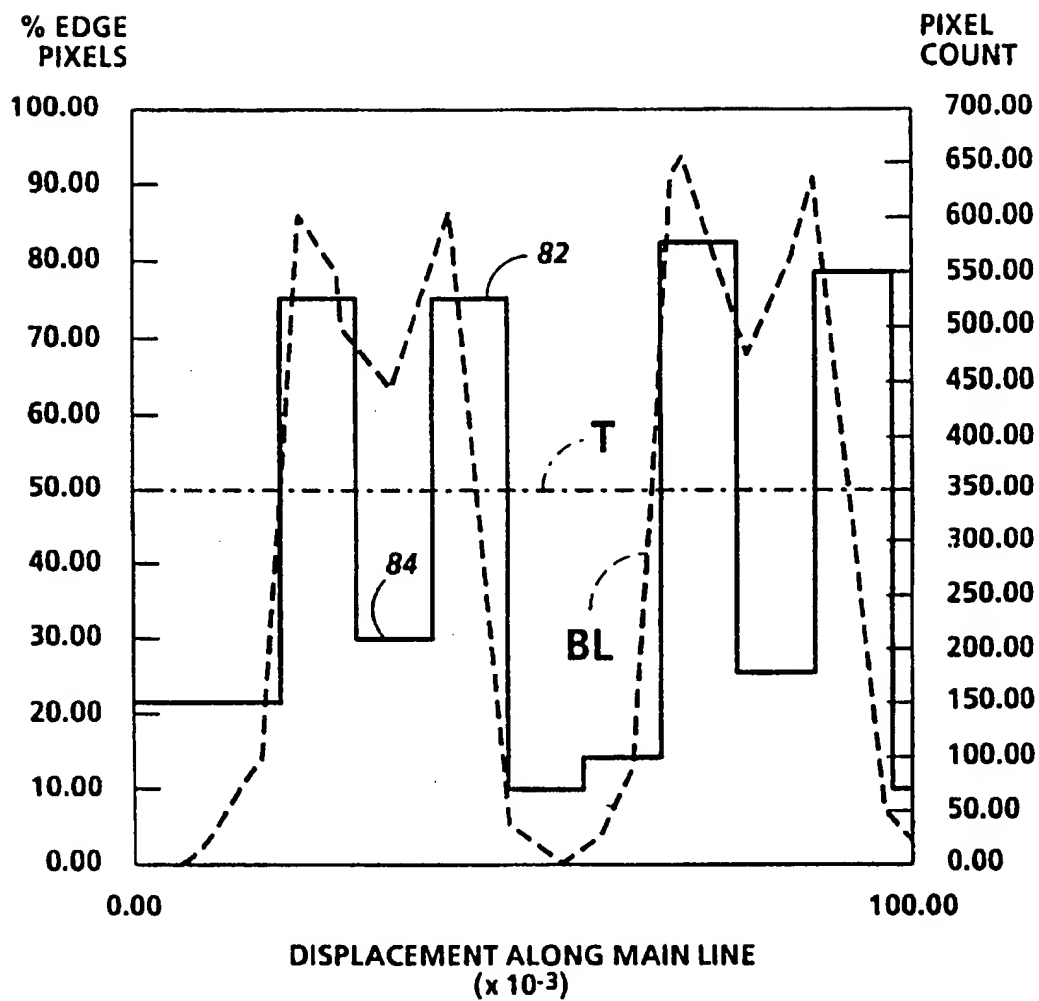


FIG. 13 B

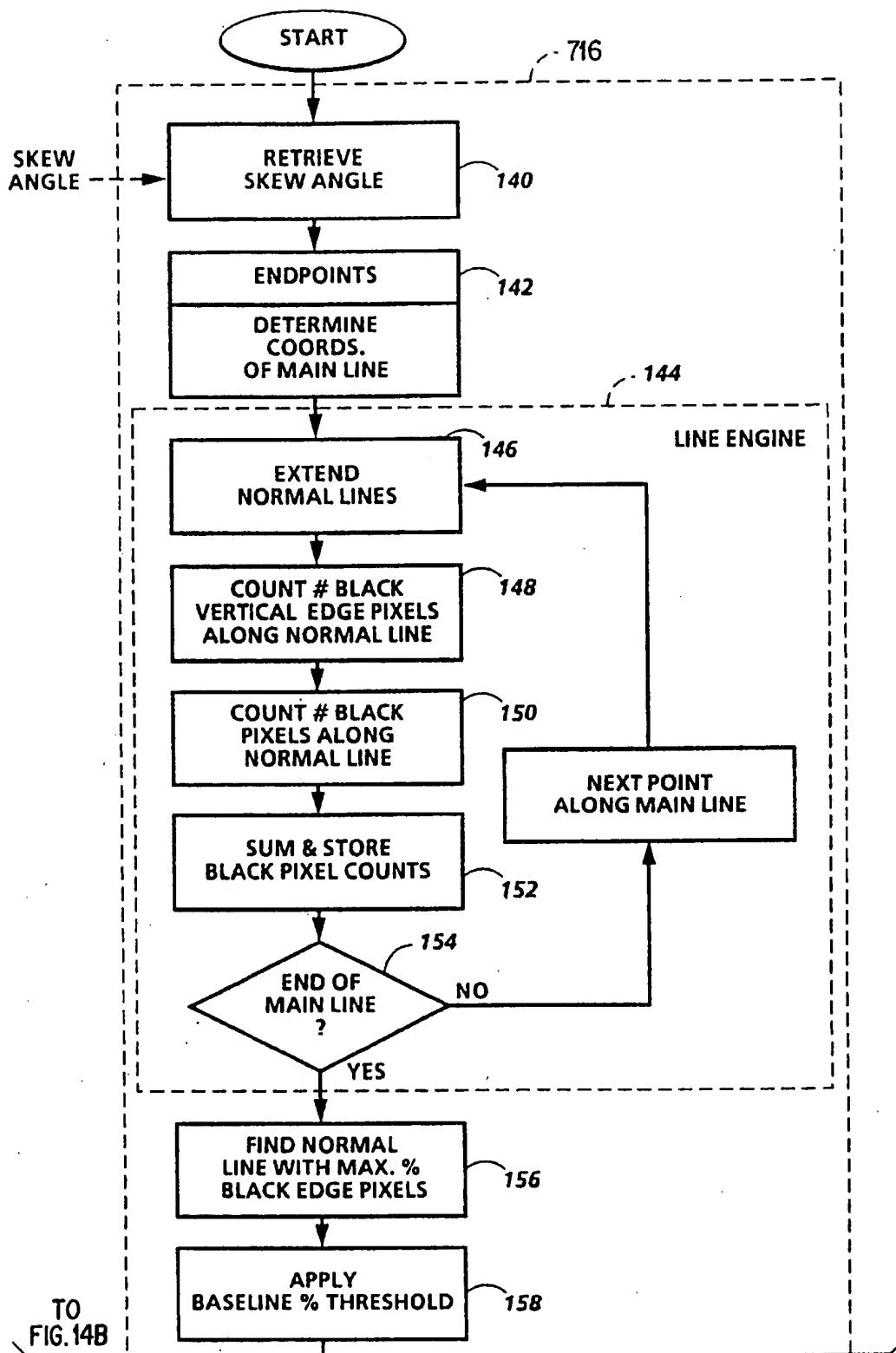
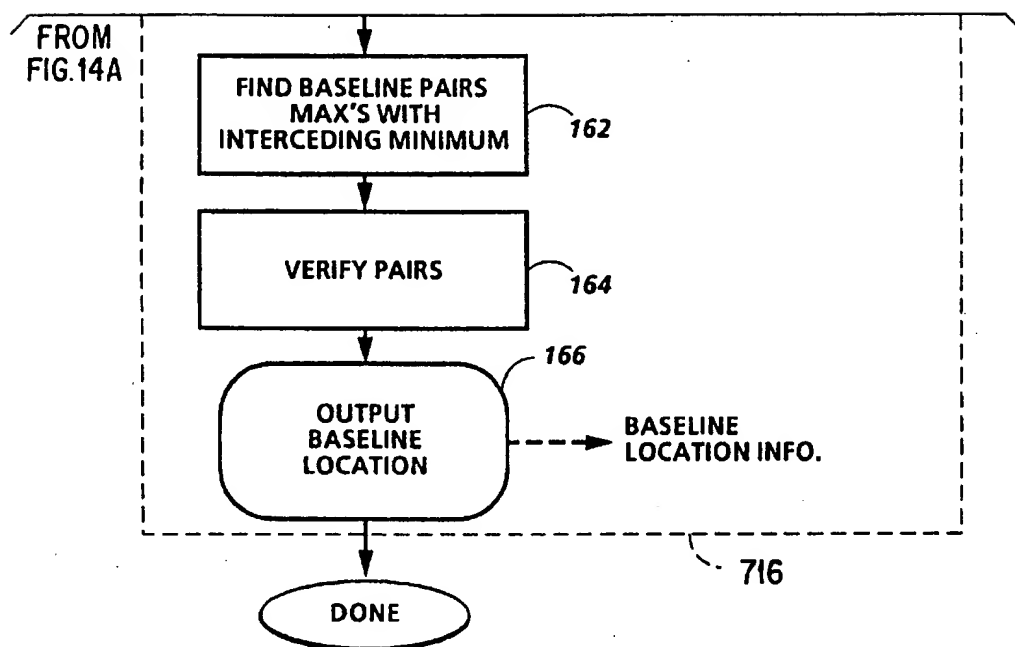


FIG. 14A



A practitioner may not solicit professional employment from a prospective client with whom the practitioner has no family or prior professional relationship, by mail, in-person or otherwise, when a significant motive for the practitioner's doing so is the practitioner's pecuniary gain under circumstances evidencing undue influence, in-

FIG. 15

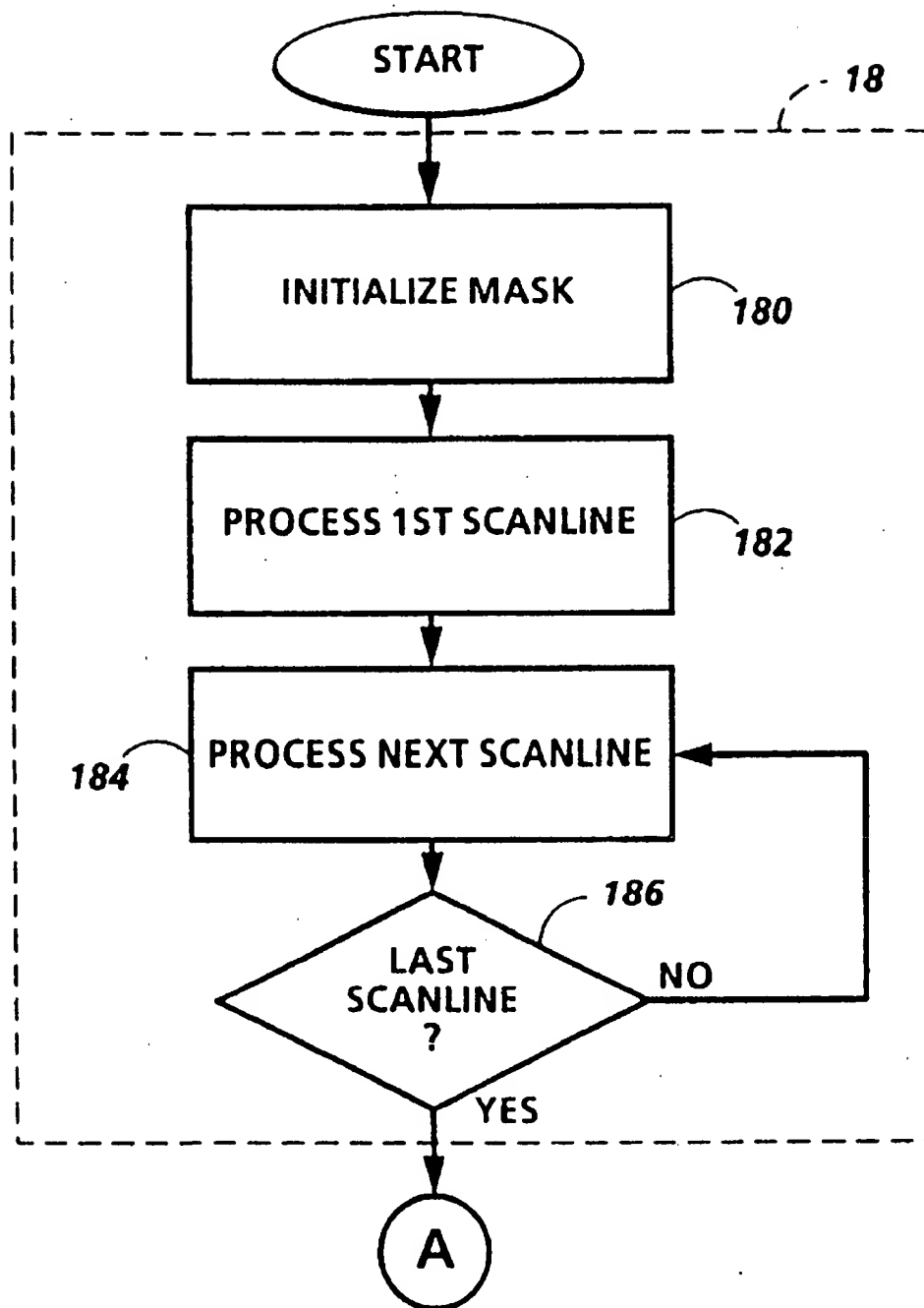


FIG. 16

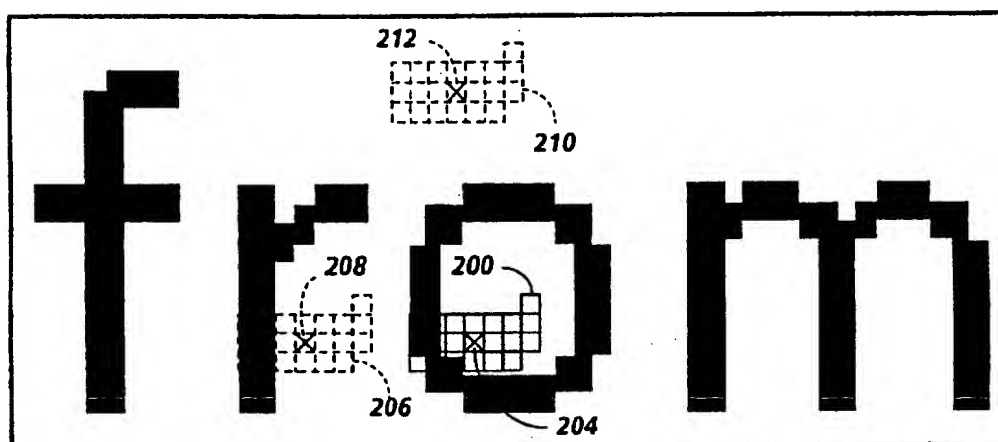


FIG. 17

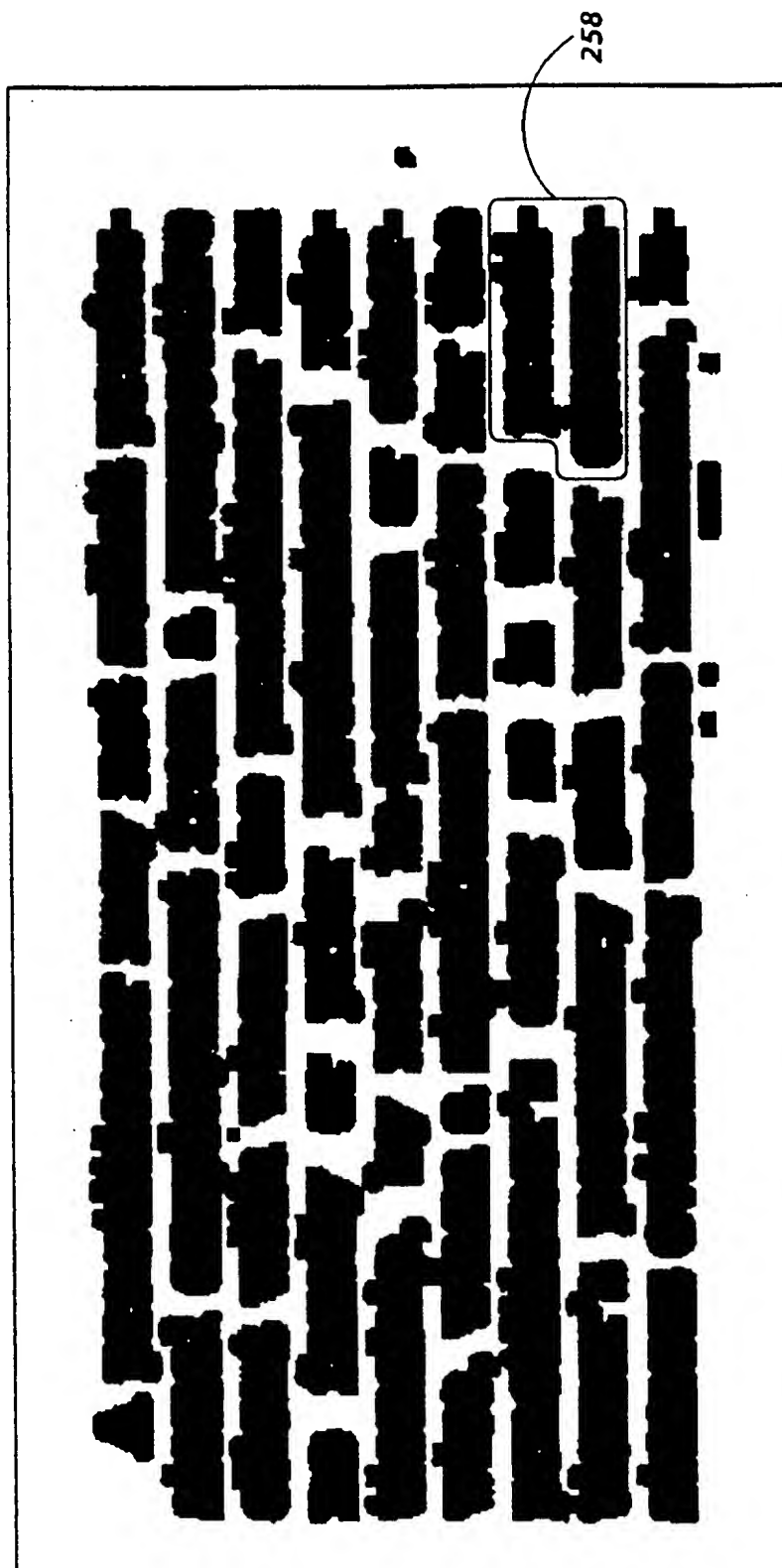


FIG. 18

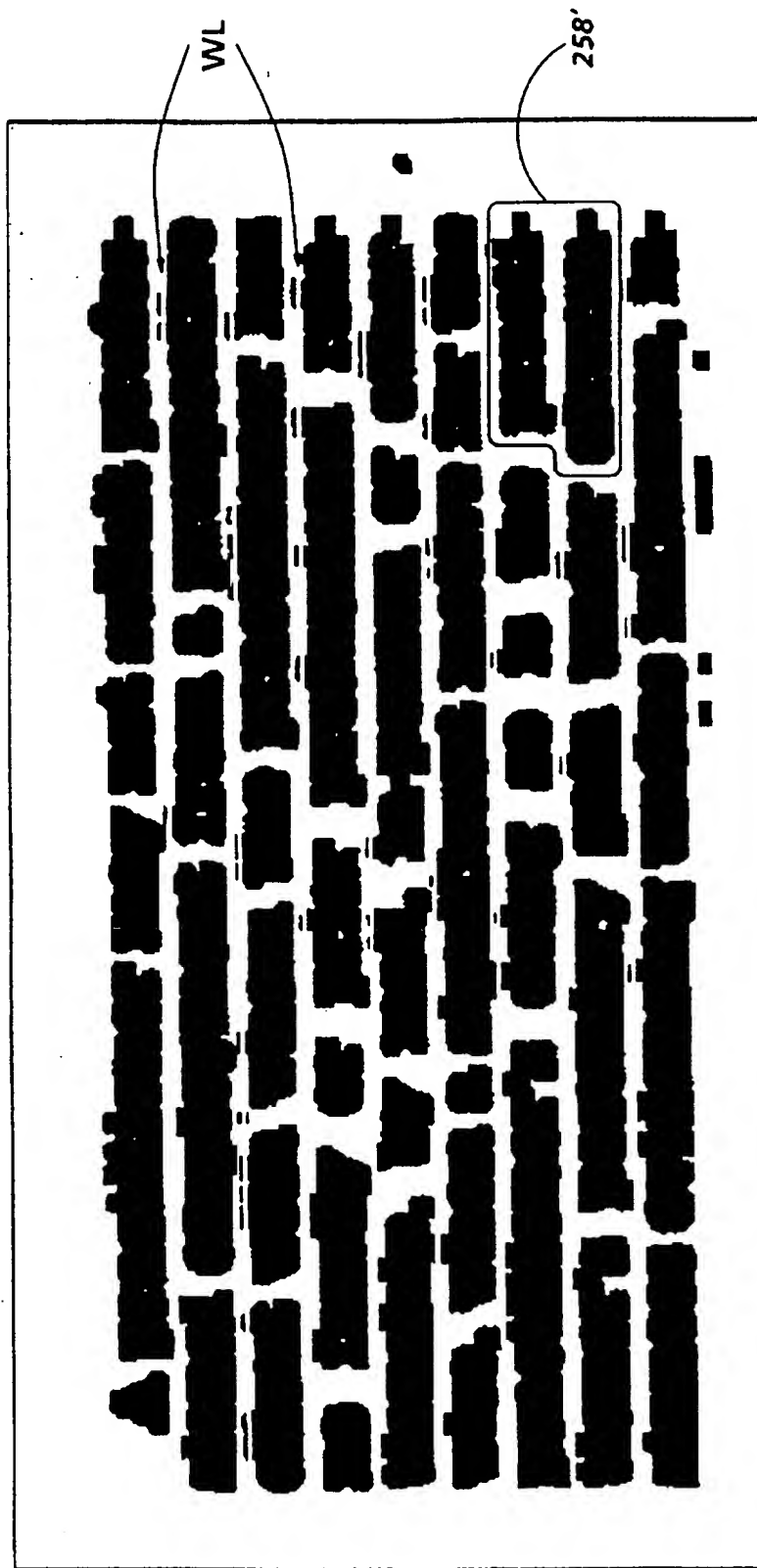
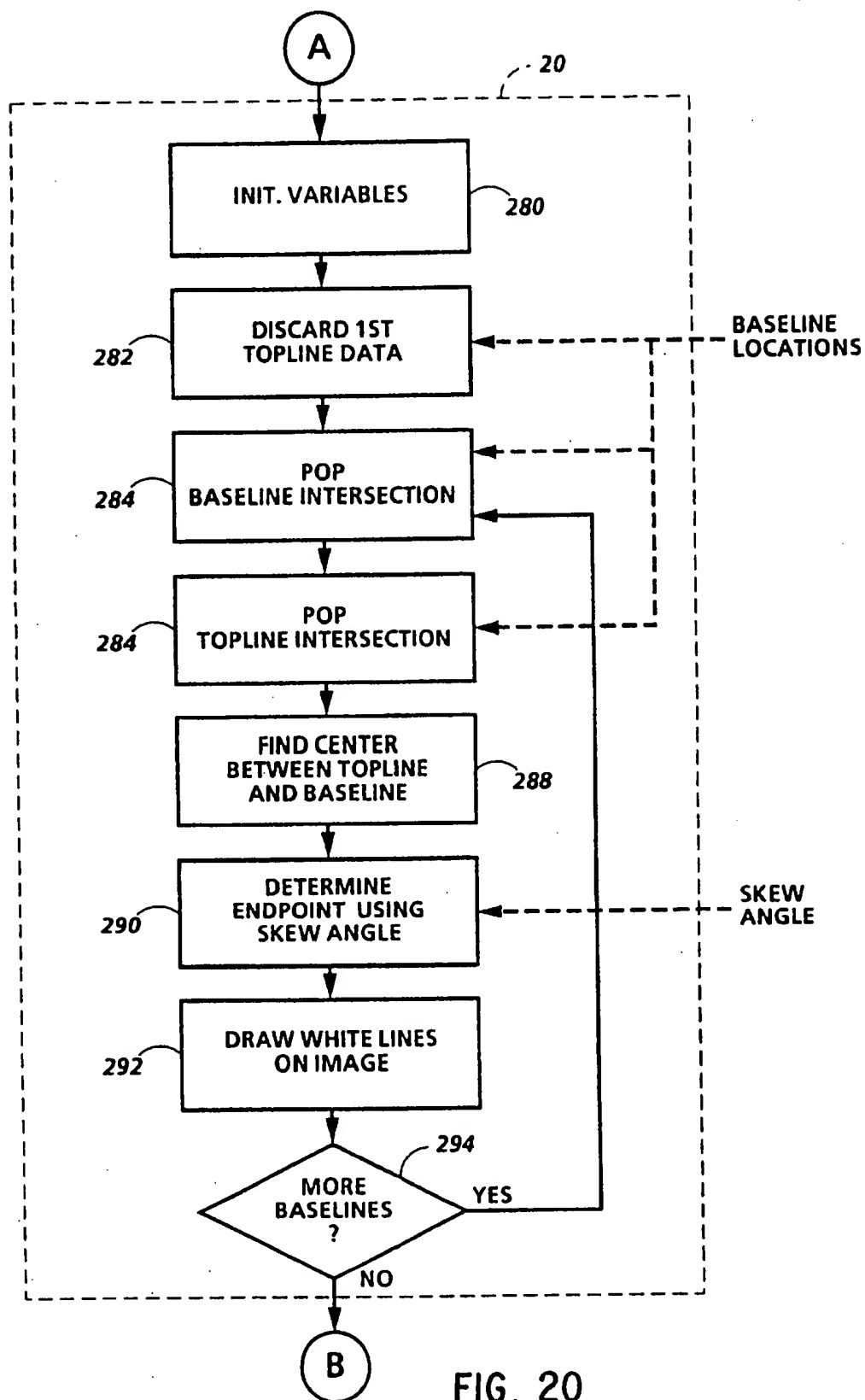


FIG. 19



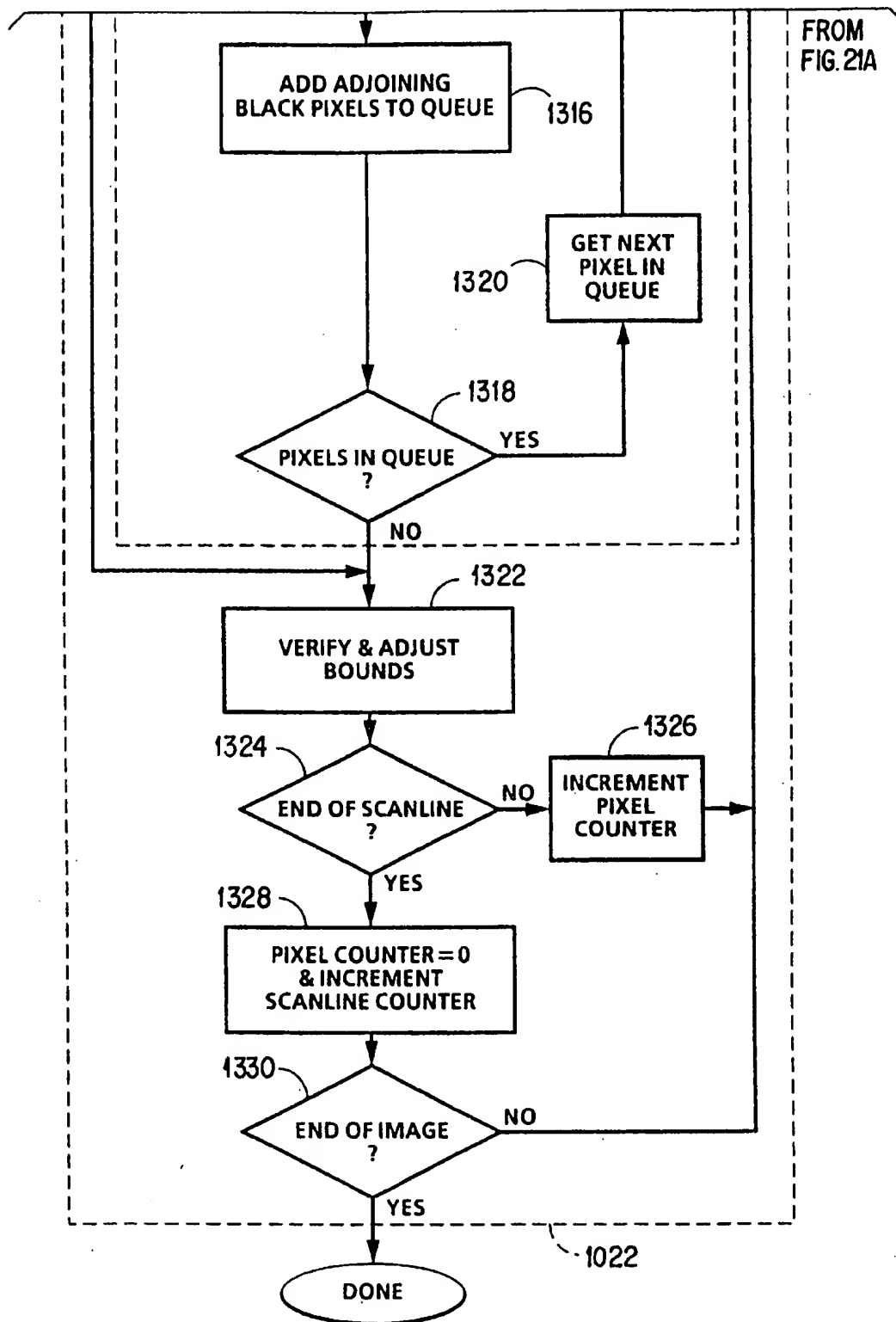


FIG. 21B

A practitioner may not solicit professional employment from a prospective client with whom the practitioner has no family or prior professional relationship, by mail, in-person or otherwise, when a significant motive for the practitioner's doing so is the practitioner's pecuniary gain under circumstances evidencing undue influence, in-

70a 72

FIG. 22

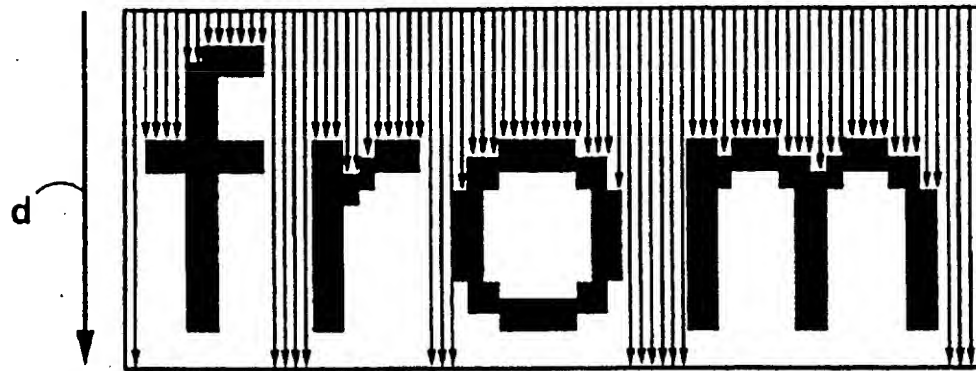


FIG. 23A

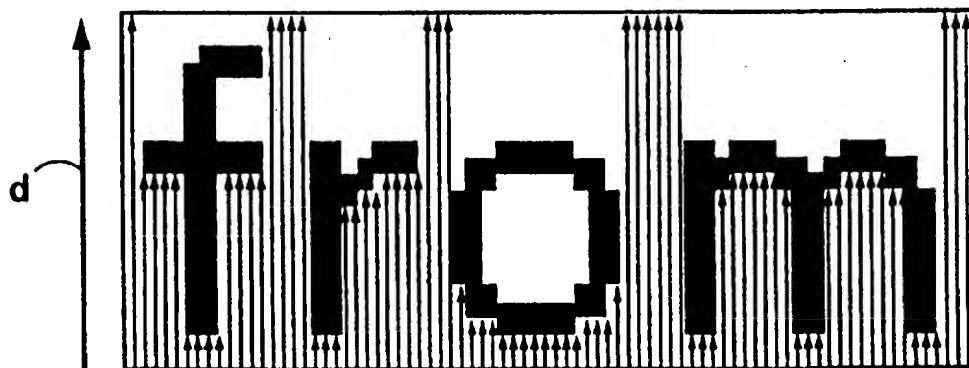


FIG. 23B

A processor may not select profiles from among a predetermined set of profiles when the processor is in a state of high performance. For example, by using, instead of other, a different set of profiles for the processor's clock so as to provide the processor's clock with a more efficient and accurate indication of the processor's performance.

FIG. 24

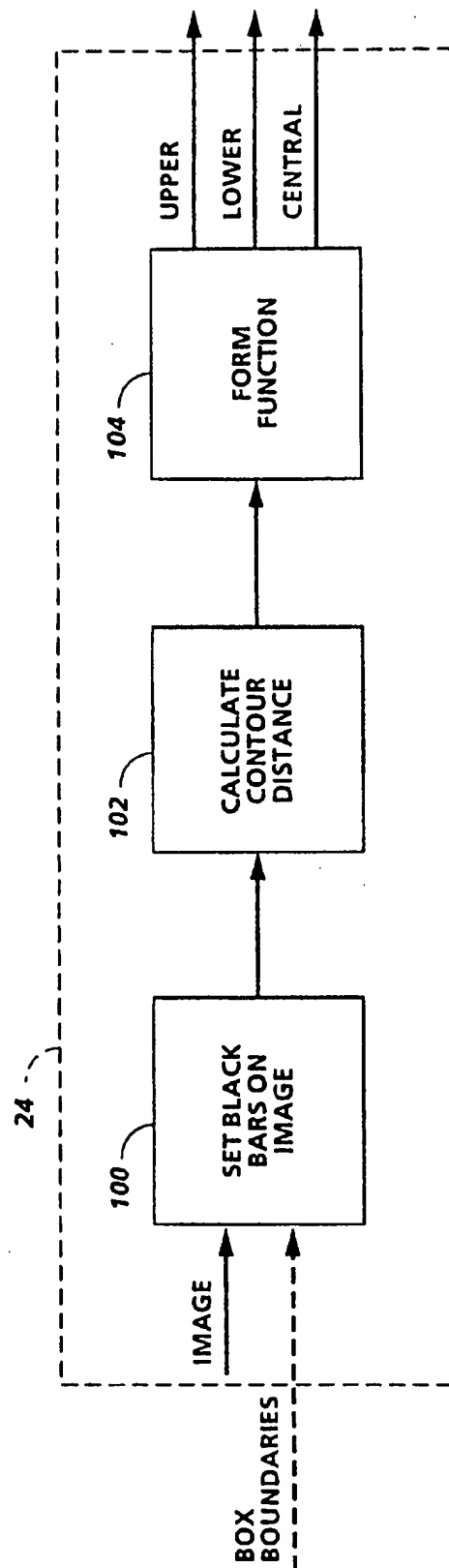


FIG. 25

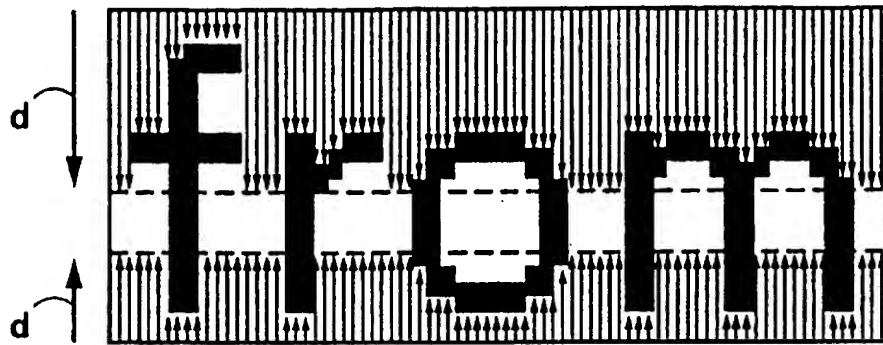


FIG. 26A

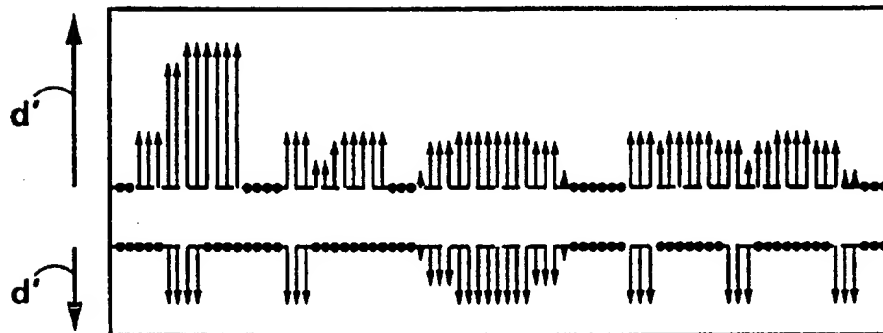


FIG. 26B

FIG. 26C



FIG. 26D

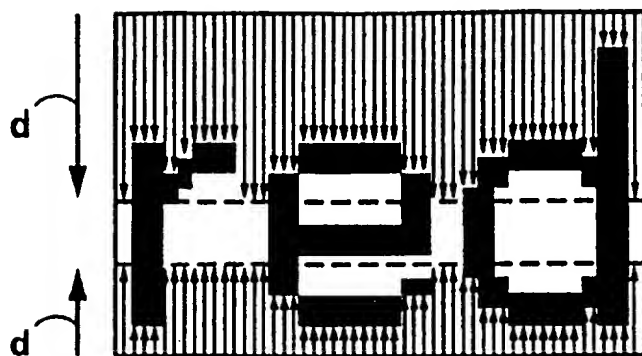


FIG. 27A

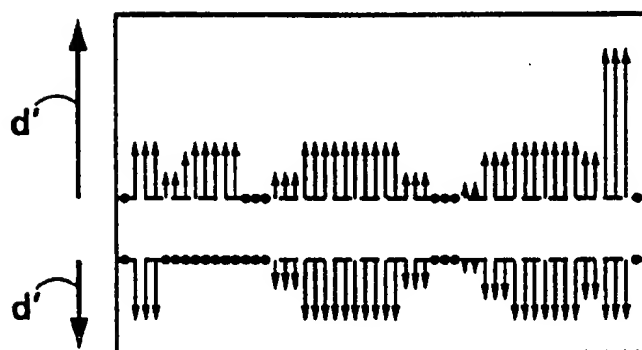


FIG. 27B

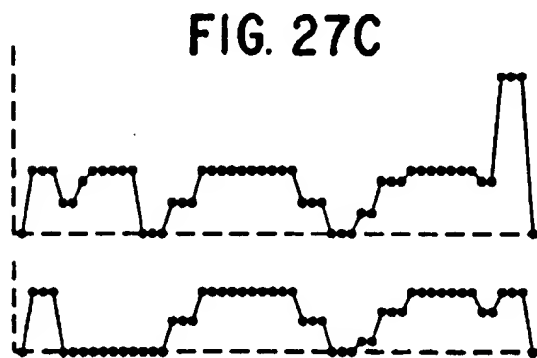


FIG. 27D

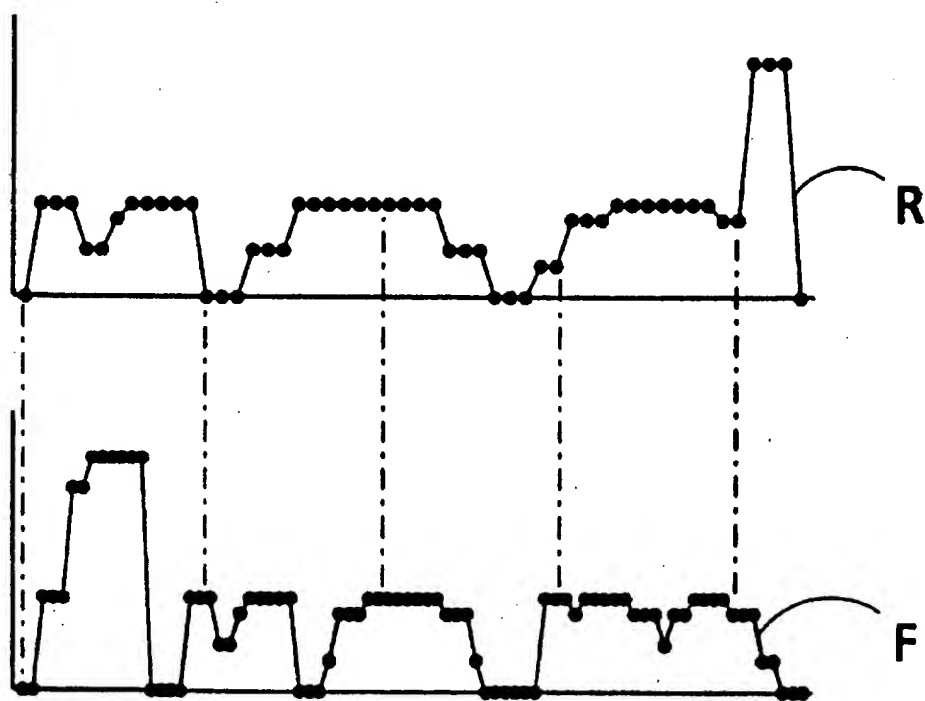


FIG. 28

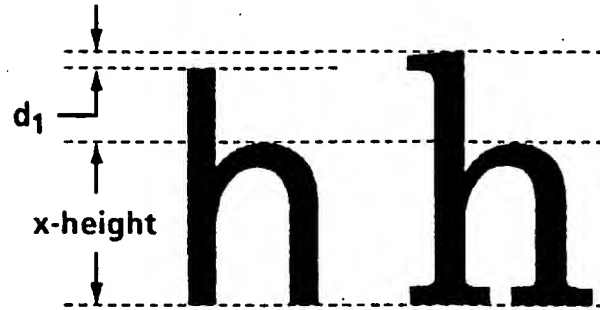


FIG. 29A

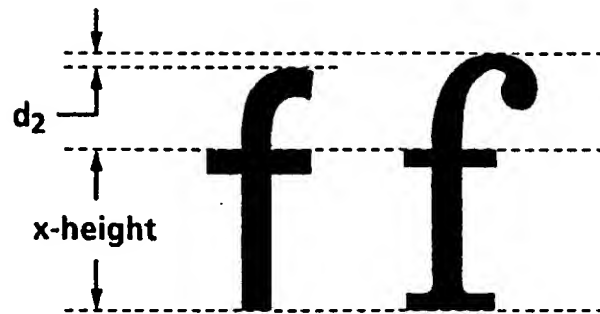


FIG. 29B



FIG. 29C

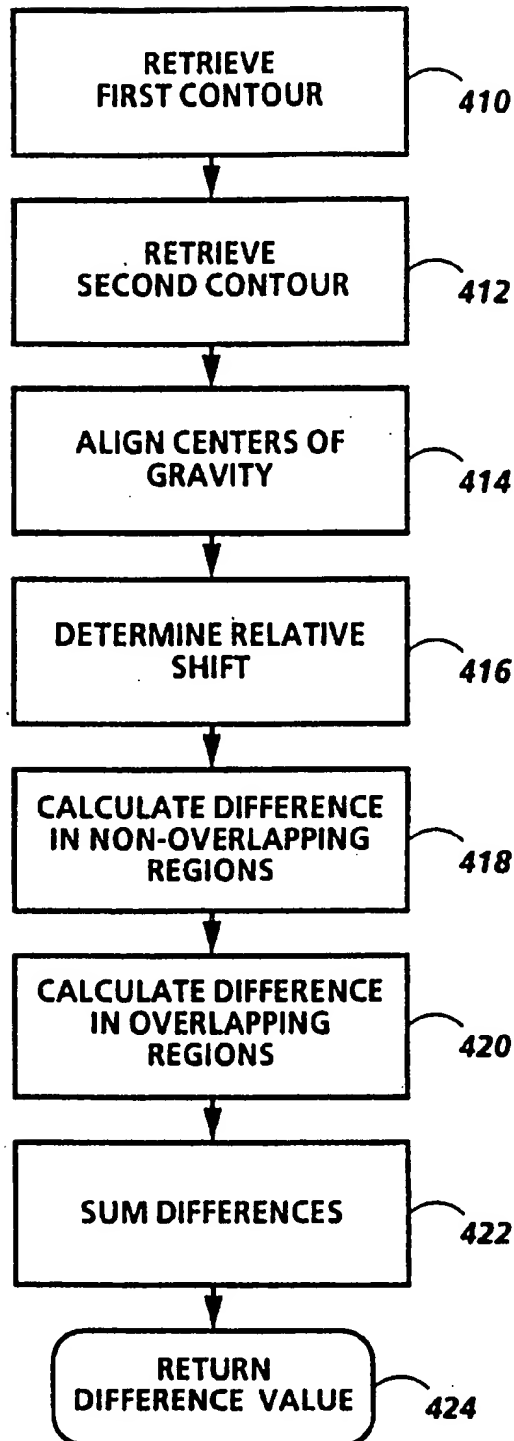


FIG. 30

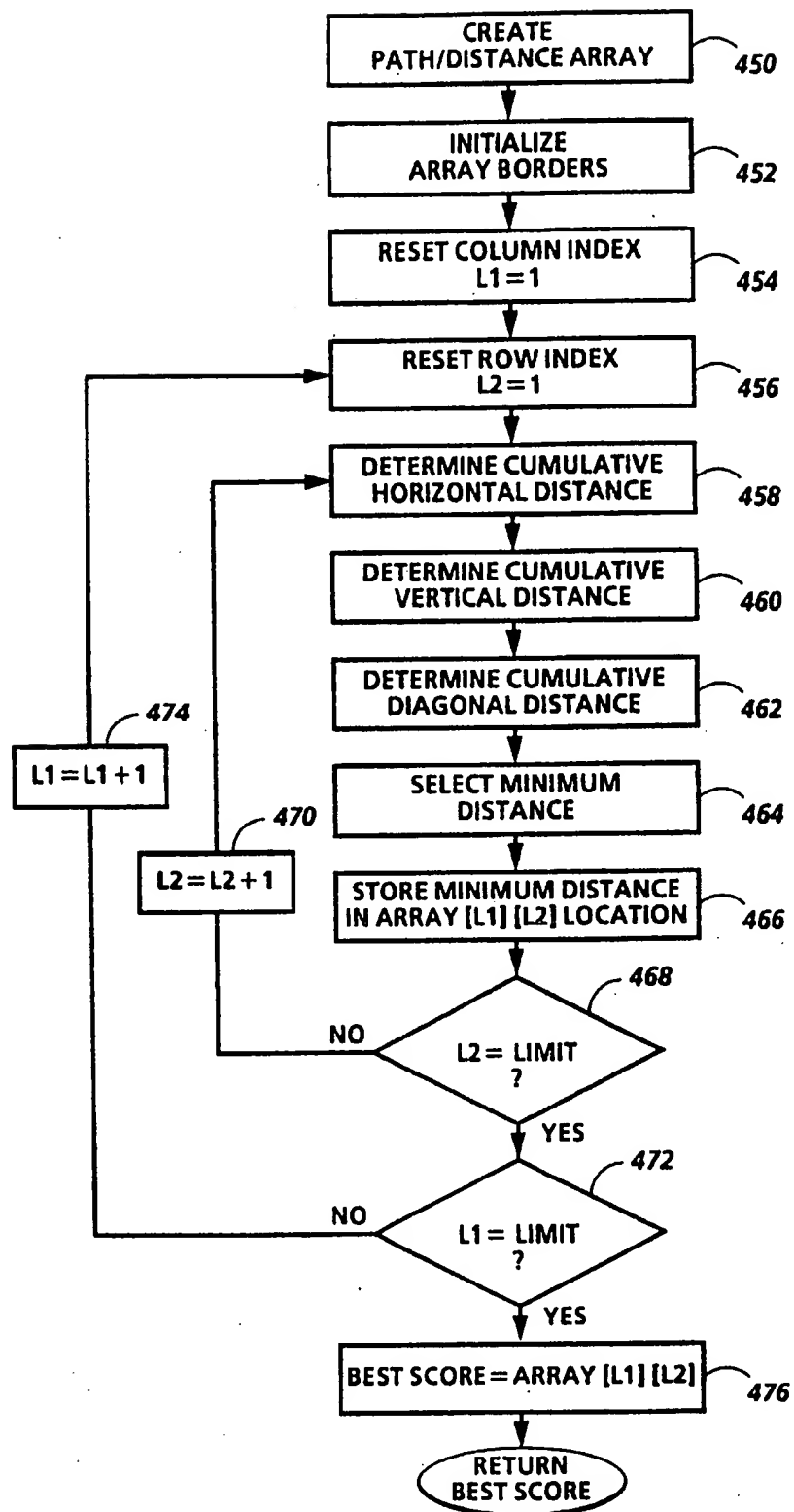


FIG. 31

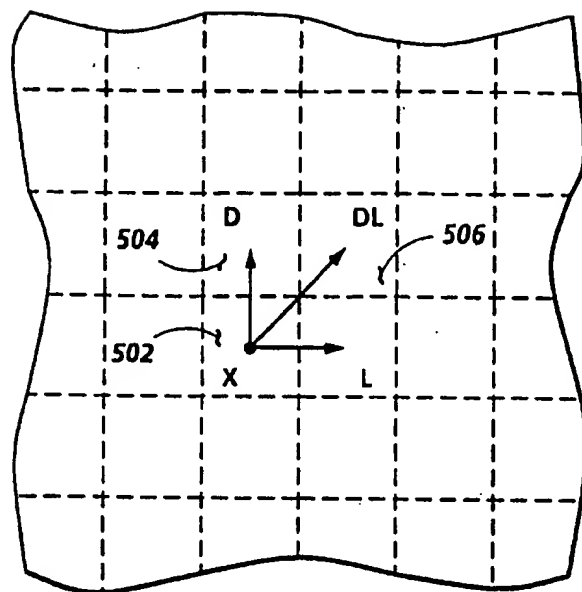


FIG. 32A

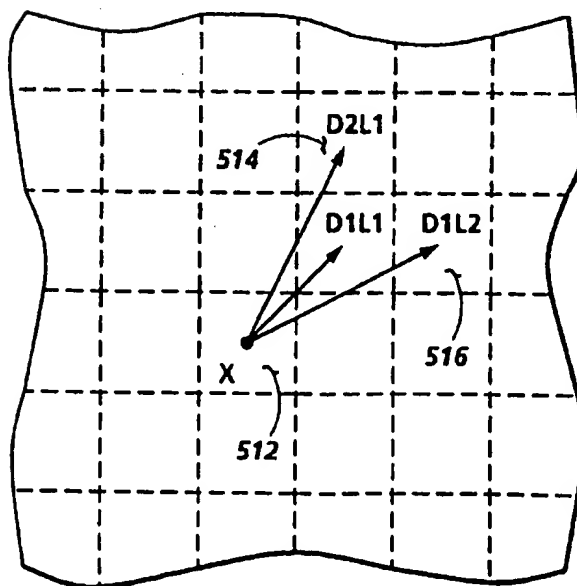
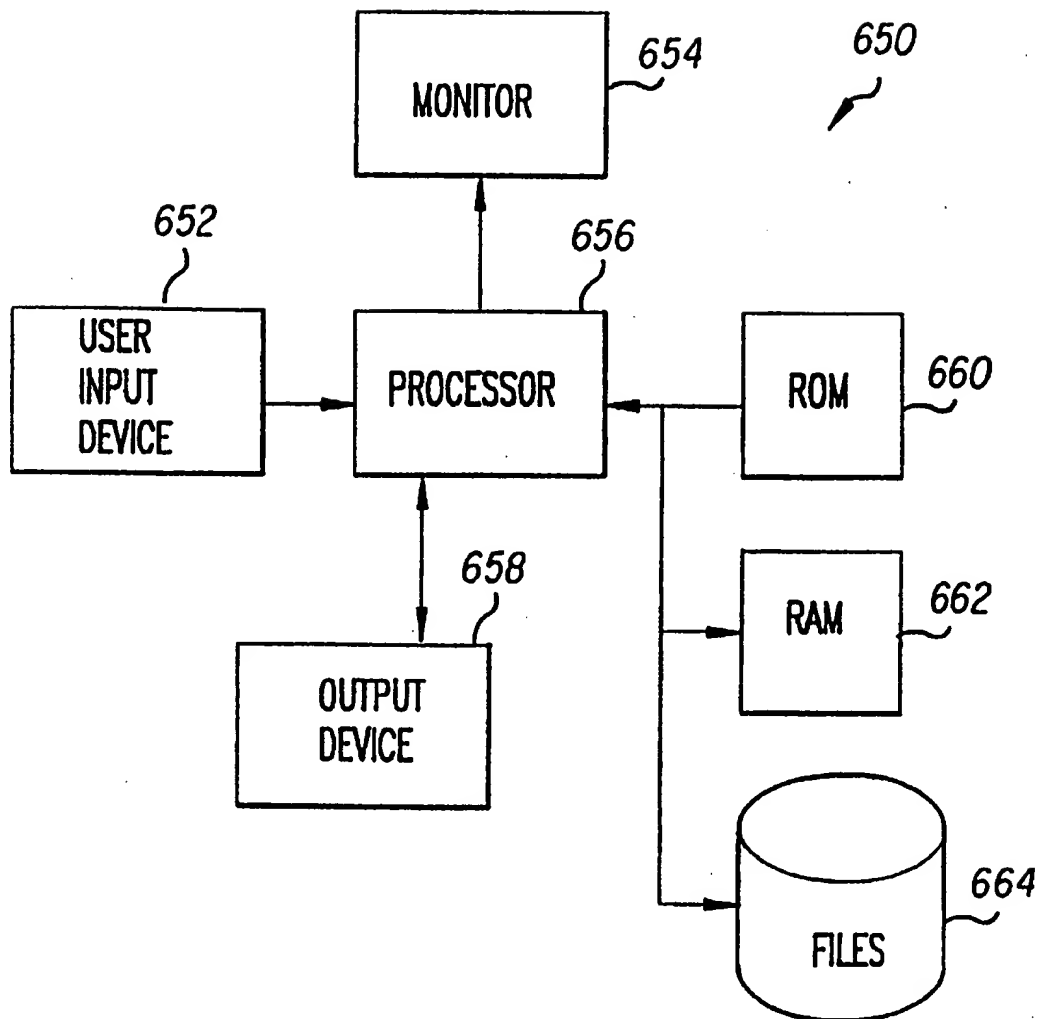


FIG. 32B

**FIG. 33**

METHOD AND APPARATUS FOR SUMMARIZING A DOCUMENT WITHOUT DOCUMENT IMAGE DECODING

This is a continuation of application Ser. No. 07/794,543 filed Nov. 19, 1991, now abandoned.

BACKGROUND OF THE INVENTION

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1. Cross-References to Related Applications

The following concurrently filed and related U.S. applications are hereby cross referenced and incorporated by reference in their entirety.

"Method for Determining Boundaries of Words in Text" to Huttenlocher et al., U.S. patent application Ser. No. 07/794,392.

"Detecting Function Words Without Converting a Document to Character Codes" to Bloomberg et al., U.S. patent application Ser. No. 07/794,190.

"A Method of Deriving Wordshapes for Subsequent Comparison" to Huttenlocher et al., U.S. patent application Ser. No. 07/794,391.

"Method and Apparatus for Determining the Frequency of Words in a Document Without Document Image Decoding" to Cass et al., U.S. patent application Ser. No. 07/795,173.

"Optical Word Recognition by Examination of Word Shape" to Huttenlocher et al., U.S. patent application Ser. No. 07/796,119, Published European Application No. 0543592, published May 26, 1993.

"A Method and Apparatus for Automatic Modification of Selected Semantically Significant Image Segments Within a Document Without Document Image Decoding" to Huttenlocher et al., U.S. patent application Ser. No. 07/795,174.

"Method for Comparing Word Shapes" to Huttenlocher et al., U.S. patent application Ser. No. 07/795,169.

"Method and Apparatus for Determining the Frequency of Phrase in a Document Without Image Decoding" to Withgott et al., U.S. patent application Ser. No. 07/794,555 now U.S. Pat. No. 5,369,714.

2. Field of the Invention

This invention relates to improvements in methods and apparatuses for automatic document processing, and more particularly to improvements in methods and apparatuses for recognizing semantically significant words, characters, images, or image segments in a document image without first decoding the document image and automatically creating a summary version of the document contents.

3. Background

It has long been the goal in computer based electronic document processing to be able, easily and reliably, to identify, access and extract information contained in electronically encoded data representing documents; and to summarize and characterize the information contained in a document or corpus of documents which has been electronically stored. For example, to facilitate review and evaluation of the information content of a document or corpus of documents to determine the relevance of same for a par-

ticular user's needs, it is desirable to be able to identify the semantically most significant portions of a document, in terms of the information they contain; and to be able to present those portions in a manner which facilitates the user's recognition and appreciation of the document contents. However, the problem of identifying the significant portions within a document is particularly difficult when dealing with images of the documents (bitmap image data), rather than with code representations thereof (e.g., coded representations of text such as ASCII). As opposed to ASCII text files, which permit users to perform operations such as Boolean algebraic key word searches in order to locate text of interest, electronic documents which have been produced by scanning an original without decoding to produce document images are difficult to evaluate without exhaustive viewing of each document image, or without hand-crafting a summary of the document for search purposes. Of course, document viewing or creation of a document summary require extensive human effort.

On the other hand, current image recognition methods, particularly involving textual material, generally involve dividing an image segment to be analyzed into individual characters which are then deciphered or decoded and matched to characters in a character library. One general class of such methods includes optical character recognition (OCR) techniques. Typically, OCR techniques enable a word to be recognized only after each of the individual characters of the word have been decoded, and a corresponding word image retrieved from a library.

Moreover, optical character recognition decoding operations generally require extensive computational effort, generally have a non-trivial degree of recognition error, and often require significant amounts of time for image processing, especially with regard to word recognition. Each bitmap of a character must be distinguished from its neighbors, its appearance analyzed, and identified in a decision making process as a distinct character in a predetermined set of characters. Further, the image quality of the original document and noise inherent in the generation of a scanned image contribute to uncertainty regarding the actual appearance of the bitmap for a character. Most character identifying processes assume that a character is an independent set of connected pixels. When this assumption fails due to the quality of the image, identification also fails.

4. References

European patent application number 0-361-464 by Doi describes a method and apparatus for producing an abstract of a document with correct meaning precisely indicative of the content of the document. The method includes listing hint words which are preselected words indicative of the presence of significant phrases that can reflect content of the document, searching all the hint words in the document, extracting sentences of the document in which any one of the listed hint words is found by the search, and producing an abstract of the document by juxtaposing the extracted sentences. Where the number of hint words produces a lengthy excerpt, a morphological language analysis of the abstracted sentences is performed to delete unnecessary phrases and focus on the phrases using the hint words as the right part of speech according to a dictionary containing the hint words.

"A Business Intelligence System" by Luhn, IBM Journal, October 1958 describes a system which in part, auto-abstracts a document, by ascertaining the most frequently occurring words (significant words) and analyzes all sentences in the text containing such words. A relative value of the sentence significance is then established by a formula

which reflects the number of significant words contained in a sentence and the proximity of these words to each other within the sentence. Several sentences which rank highest in value of significance are then extracted from the text to constitute the auto-abstract.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the invention to provide a method and apparatus for automatically excerpting and summarizing a document image without decoding or otherwise understanding the contents thereof.

It is another object of the invention to provide a method and apparatus for automatically generating ancillary document images reflective of the contents of an entire primary document image.

It is another object of the invention to provide a method and apparatus of the type described for automatically extracting summaries of material and providing links from the summary back to the original document.

It is another object of the invention to provide a method and apparatus of the type described for producing Braille document summaries or speech synthesized summaries of a document.

It is another object of the invention to provide a method and apparatus of the type described which is useful for enabling document browsing through the development of image gists, or for document categorization through the use of lexical gists.

It is another object of the invention to provide a method and apparatus of the type described that does not depend upon statistical properties of large, pre-analyzed document corpora.

The invention provides a method and apparatus for segmenting an undecoded document image into undecoded image units, identifying semantically significant image units based on an evaluation of predetermined image characteristics of the image units, without decoding the document image or reference to decoded image data, and utilizing the identified significant image units to create an ancillary document image of abbreviated information content which is reflective of the subject matter content of the original document image. In accordance with one aspect of the invention, the ancillary document image is a condensation or summarization of the original document image which facilitates browsing. In accordance with another aspect of the invention, the identified significant image units are presented as an index of key words, which may be in decoded form, to permit document categorization.

Thus, in accordance with one aspect of the invention, a method is presented for excerpting information from a document image containing word image units. According to the invention, the document image is segmented into word image units (word units), and the word units are evaluated in accordance with morphological image properties of the word units, such as word shape. Significant word units are then identified, in accordance with one or more predetermined or user selected significance criteria, and the identified significant word units are outputted.

In accordance with another aspect of the invention, an apparatus is provided for excerpting information from a document containing a word unit text. The apparatus includes an input means for inputting the document and producing a document image electronic representation of the document, and a data processing system for performing data

driven processing and which comprises execution processing means for performing functions by executing program instructions in a predetermined manner contained in a memory means. The program instructions operate the execution processing means to identify significant word units in accordance with a predetermined significance criteria from morphological properties of the word units, and to output selected ones of the identified significant word units. The output of the selected significant word units can be to an electrostatographic reproduction machine, a speech synthesizer means, a Braille printer, a bitmap display, or other appropriate output means.

These and other objects, features and advantages of the invention will be apparent to those skilled in the art from the following detailed description of the invention, when read in conjunction with the accompanying drawings and appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

A preferred embodiment of the invention is illustrated in the accompanying drawing, in which:

FIG. 1 is a flow chart of a method of the invention;

FIG. 2 is a block diagram of an apparatus according to the invention for carrying out the method of FIG. 1;

FIG. 3 is a flow chart of a preferred embodiment of a method according to the invention for detecting function words in a scanned document image without first converting the document image to character codes;

FIGS. 4A-4F show three sets of character ascender structuring elements where: FIGS. 4A-4B show a set of character ascender structuring elements of height 3 and length 5, where the solid dots are ON pixels along the bottom row and along one side column and there are one or more OFF pixels in a remaining location preferably separated from the ON pixels; FIGS. 4C-4D show a set of character ascender structuring elements of height 4 and length 5; and FIGS. 4E-4F show a set of character ascender structuring elements of height 5 and length 5.

FIGS. 5A-5F show three sets of character descender structuring elements where: FIGS. 5A-5B show a set of character descender structuring elements of height 3 and length 5; FIGS. 5C-5D show a set of character descender structuring elements of height 4 and length 5; and FIGS. 5E-5F show a set of character descender structuring elements of height 5 and length 5;

FIG. 6 shows a horizontal structuring element of length 5;

FIG. 7 shows a block system diagram of the arrangement of system components forming a word shape recognition system;

FIG. 8 shows a block system diagram for identifying equivalence classes of image units; and

FIG. 9 shows a block system diagram for identifying significant image units.

FIG. 10 shows an image sample of example text over which the inventive process will be demonstrated;

FIG. 11 is a copy of a scanned image of the example text;

FIGS. 12A, 12B and 12C graphically illustrate the process used to determine the angle at which the example text is oriented in the image sample prior for further processing, while FIG. 12D shows graphs of the responses taken from the example text, which are used to determine the angle at which the example text is oriented in the image sample prior to further processing;

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FIGS. 13A and 13B respectively show the derivation and use of a graph examining the sample image of the example text to determine baselines of text within the image;

FIGS. 14A and 14B are flowcharts illustrating the procedures executed to determine the baselines shown in FIG. 13A;

FIG. 15 shows the scanned image of the example text with baselines indicated thereon after derivation from the data shown in FIGS. 13A and 13B;

FIG. 16 is a flowchart illustrating the steps used in the application of a median filter to the image of FIG. 10;

FIG. 17 is an enlarged pictorial representation of a portion of the image of FIG. 10, illustrating the application of the median filter;

FIG. 18 demonstrates the resulting image after application of a median filter, a process known herein as blobifying, to the scanned image of the example text, which tends to render character strings as a single set of connected pixels;

FIG. 19 shows a subsequent step in the process, in which lines of white pixels are added to the blurred image to clearly delineate a line of character strings from adjacent lines of character strings;

FIG. 20 is a flowchart illustrating the steps required to add the white lines of FIG. 19;

FIGS. 21A and 21B are flowcharts representing the procedure which is followed to segment the image data in accordance with the blurred image of FIG. 18;

FIG. 22 shows the sample text with bounding boxes placed around each word group in a manner which uniquely identifies a subset of image pixels containing each character string;

FIGS. 23A and 23B illustrate derivation of a single independent value signal, using the example word "from", which appears in the sample image of example text;

FIG. 24 illustrates the resulting contours formed by the derivation process illustrated in FIGS. 23A and 23B;

FIG. 25 illustrates the steps associated with deriving the word shape signals;

FIGS. 26A, 26B, 26C and 26D illustrate derivation of a single independent value signal, using the example word "from";

FIGS. 27A, 27B, 27C and 27D illustrate derivation of a single independent value signal, using the example word "red", which does not appear in the sample image of example text;

FIG. 28 shows a simple comparison of the signals derived for the words "red" and "from" using a signal normalization method;

FIGS. 29A, 29B, and 29C illustrate the details of the discrepancy in font height, and the method for normalization of such discrepancies;

FIG. 30 is a flowchart detailing the steps used for one method of determining the relative difference between word shape contours;

FIG. 31 is a flowchart detailing the steps of a second method for determining the relative difference between word shape contours;

FIGS. 32A and 32B are respective illustrations of the relationship between the relative difference values calculated and stored in an array, for both a non-slope-constrained and a slope-constrained comparison; and

FIG. 33 is a block diagram of a preferred embodiment of an apparatus according to the invention for detecting func-

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tion words in a scanned document image without first converting the document image to character codes;

The Appendix contains source code listings for a series of image manipulation and signal processing routines which have been implemented to demonstrate the functionality of the present invention. Included in the Appendix are four sections which are organized as follows:

Section A, beginning at page 1, comprises the declarative or "include" files which are commonly shared among the functional code modules;

Section B, beginning at page 26, includes the listings for a series of library type functions used for management of the images, error reporting, argument parsing, etc.;

Section C, beginning at page 42, comprises numerous variations of the word shape comparison code, and further includes code illustrating alternative comparison techniques than those specifically cited in the following description;

Section D, beginning at page 145, comprises various functions for the word shape extraction operations that are further described in the following description.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In contrast to prior techniques, such as those described above, the invention is based upon the recognition that scanned image files and character code files exhibit important differences for image processing, especially in data retrieval. The method of a preferred embodiment of the invention capitalizes on the visual properties of text contained in paper documents, such as the presence or frequency of linguistic terms (such as words of importance like "important", "significant", "crucial", or the like) used by the author of the text to draw attention to a particular phrase or a region of the text; the structural placement within the document image of section titles and page headers, and the placement of graphics; and so on. A preferred embodiment of the method of the invention is illustrated in the flow chart of FIG. 1, and an apparatus for performing the method is shown in FIG. 2. For the sake of clarity, the invention will be described with reference to the processing of a single document. However, it will be appreciated that the invention is applicable to the processing of a corpus of documents containing a plurality of documents. More particularly, the invention provides a method and apparatus for automatically excerpting semantically significant information from the data or text of a document based on certain morphological (structural) image characteristics of image units corresponding to units of understanding contained within the document image. The excerpted information can be used, among other things, to automatically create a document index or summary. The selection of image units for summarization can be based on frequency of occurrence, or predetermined or user selected selection criteria, depending upon the particular application in which the method and apparatus of the invention is employed.

The invention is not limited to systems utilizing document scanning. Rather, other systems such as a bitmap workstation (i.e., a workstation with a bitmap display) or a system using both bitmapping and scanning would work equally well for the implementation of the methods and apparatus described herein.

With reference first to FIG. 2, the method is performed on an electronic image of an original document 5, which may include lines of text 7, titles, drawings, figures 8, or the like, contained in one or more sheets or pages of paper 10 or other

tangible form. The electronic document image to be processed is created in any conventional manner, for example, by a conventional scanning means such as those incorporated within a document copier or facsimile machine, a Braille reading machine, or by an electronic beam scanner or the like. Such scanning means are well known in the art, and thus are not described in detail herein. An output derived from the scanning is digitized to produce undecoded bit mapped image data representing the document image for each page of the document, which data is stored, for example, in a memory 15 of a special or general purpose digital computer data processing system 13. The data processing system 13 can be a data driven processing system which comprises sequential execution processing means 16 for performing functions by executing program instructions in a predetermined sequence contained in a memory, such as the memory 15. The output from the data processing system 13 is delivered to an output device 17, such as, for example, a memory or other form of storage unit; an output display 17A as shown, which may be, for instance, a CRT display; a printer device 17B as shown, which may be incorporated in a document copier machine or a Braille or standard form printer; a facsimile machine, speech synthesizer or the like.

Through use of equipment such as illustrated in FIG. 2, the identified word units are detected based on significant morphological image characteristics inherent in the image units, without first converting the scanned document image to character codes.

The method by which such image unit identification may be performed is described with reference now to FIG. 1. The first phase of the image processing technique of the invention involves a low level document image analysis in which the document image for each page is segmented into undecoded information containing image units (step 20) using conventional image analysis techniques; or, in the case of text documents, preferably using the bounding box method described in copending U.S. patent application Ser. No. 07/794,392 filed concurrently herewith by Huttenlocher and Hopcroft, and entitled "Method for Determining Boundaries of Words in Text." The locations of and spatial relationships between the image units on a page are then determined (step 25). For example, an English language document image can be segmented into word image units based on the relative difference in spacing between characters within a word and the spacing between words. Sentence and paragraph boundaries can be similarly ascertained. Additional region segmentation image analysis can be performed to generate a physical document structure description that divides page images into labelled regions corresponding to auxiliary document elements like figures, tables, footnotes and the like. Figure regions can be distinguished from text regions based on the relative lack of image units arranged in a line within the region, for example. Using this segmentation, knowledge of how the documents being processed are arranged (e.g., left-to-right, top-to-bottom), and, optionally, other inputted information such as document style, a "reading order" sequence for word images can also be generated. The term "image unit" is thus used herein to denote an identifiable segment of an image such as a number, character, glyph, symbol, word, phrase or other unit that can be reliably extracted. Advantageously, for purposes of document review and evaluation, the document image is segmented into sets of signs, symbols or other elements, such as words, which together form a single unit of understanding. Such single units of understanding are generally characterized in an image as being separated by a spacing greater than that which separates the elements forming a unit, or by some

predetermined graphical emphasis, such as, for example, a surrounding box image or other graphical separator, which distinguishes one or more image units from other image units in the scanned document image. Such image units representing single units of understanding will be referred to hereinafter as "word units."

Advantageously, a discrimination step 30 is next performed to identify the image units which have insufficient information content to be useful in evaluating the subject matter content of the document being processed. One preferred method is to use the morphological function or stop word detection techniques disclosed in the copending U.S. patent application Ser. No. 07/794,190 filed concurrently herewith by D. Bloomberg et al., and entitled "Detecting Function Words Without Converting a Document to Character Codes".

The method of identification of image units which have insufficient information content by determining function words without converting the document to character codes is shown in FIG. 3. The following definitions are used to describe this method:

A binary image contains pixels that are either ON or OFF. Binary images are manipulated according to a number of operations wherein one or more source images are mapped onto a destination image. The results of such operations are generally referred to as images.

A morphological operation refers to an operation on a pixelmap image (a source image), that uses a local rule at each pixel to create another pixelmap image, the destination image. This rule depends both on the type of the desired operation to perform as well as on the chosen structuring element.

A structuring element (SE) refers to an image object of typically (but not necessarily) small size and simple shape that probes the source image and extracts various types of information from it via the chosen morphological operation. FIGS. 4 and 5 show SEs where a solid circle is a hit, and an open circle is a miss. The center position is denoted by a cross. Squares that have neither solid nor open circles are "don't cares"; their value in the image (ON or OFF) is not probed. A binary SE is used to probe binary images in a binary morphological operation that operates on binary input images and creates an output binary image. The SE is defined by a center location and a number of pixel locations, each normally having a defined value (ON or OFF). The pixels defining the SE do not have to be adjacent each other. The center location need not be at the geometrical center of the pattern; indeed it need not even be inside the pattern. A solid SE refers to an SE having a periphery within which all pixels are ON. For example, a solid 2x2 SE is a 2x2 square of ON pixels. A solid SE need not be rectangular. A horizontal SE is generally one row of ON pixels and a vertical SE is generally one column of ON pixels of selected size. A hit-miss SE refers to an SE that specifies at least one ON pixel and at least one OFF pixel.

AND, OR and XOR are logical operations carried out between two images on a pixel-by-pixel basis.

NOT is a logical operation carried out on a single image on a pixel-by-pixel basis.

EXPANSION is a scale operation characterized by a scale factor N, wherein each pixel in a source image becomes an NxN square of pixels, all having the same value as the original pixel.

REDUCTION is a scale operation characterized by a scale factor N in a threshold level M. REDUCTION with scale=N entails dividing the source image into NxN squares

of pixels, mapping each such square in the source image to a single pixel on the destination image. The value for the pixel in the destination image is determined by the threshold level M , which is a number between 1 and N^2 . If the number of ON pixels in the pixel square is greater or equal to M , the destination pixel is ON, otherwise it is OFF.

EROSION is a morphological operation wherein a given pixel in the destination image is turned ON if and only if the result of superimposing the SE center on the corresponding pixel location in the source image results in a match between all ON and OFF pixels in the SE and the underlying pixels in the source image. An EROSION will give one pixel in the destination image for every match. That is, at each pixel, it outputs 1 if the SE (shifted and centered at that pixel) is totally contained inside the original image foreground, and outputs 0 otherwise. Note that EROSION usually refers to operations using a SE with only hits and more generally matching operations with both hits and misses (often called a hit-miss transform). The term EROSION is used herein to include matching operations with both hits and misses, thus the hit-miss transform is the particular type of EROSION used herein.

DILATION is a morphological operation wherein a given pixel in the source image being ON causes the SE to be written into the destination image with the SE center at the corresponding location in the destination image. The SEs used for DILATION typically have no OFF pixels. The DILATION draws the SE as a set of pixels in the destination image for each pixel in the source image. Thus, the output image is the union of all shifted versions of the SE translated at all 1-pixels of the original image.

FillClip is a morphological operation where one image is used as a seed and is grown morphologically, clipping it at each growth step to the second image. For example, a fillClip could include a DILATION followed by logically ANDing the DILATION result with another image.

OPENING is a morphological operation that uses an image and a structuring element and consists of an EROSION followed by a DILATION. The result is to replicate the structuring element in the destination image for each match in the source image.

CLOSING is a morphological operation using an image and a structuring element. It includes a DILATION followed by an EROSION of the image by a structuring element. A CLOSE of an image is equivalent to the bit inverse of an OPEN on the (bit inverse) background.

UNION is a bitwise OR between two images. An intersection is a bitwise AND between two images.

Blurring is a DILATION of an image by a structuring element(s) consisting of two or more hits.

A mask refers to an image, normally derived from an original or source image, that contains substantially solid regions of ON pixels corresponding to regions of interest in the original image. The mask may also contain regions of ON pixels that do not correspond to regions of interest.

The various operations defined above are sometimes referred to in noun, adjective, and verb forms. For example, references to DILATION (noun form) may be in terms of DILATING the image or the image being DILATED (verb forms) or the image being subjected to a DILATION operation (adjective form). No difference in meaning is intended.

Morphological operations have several specific properties that simplify their use in the design of appropriate procedures. First, they are translationally invariant. A sideways shift of the image before transforming does not change the

result, except to shift the result as well. Operations that are translationally invariant can be implemented with a high degree of parallelism, in that each point in the image is treated using the same rule. In addition, morphological operations satisfy two properties that make it easy to visualize their geometrical behavior. First, EROSION, DILATION, OPEN and CLOSE are increasing, which means that if image 1 is contained in image 2, then any of these morphological operations on image 1 will also be contained in the morphological operation on image 2. Second, a CLOSE is extensive and OPEN is antiextensive. This means that the original image is contained in the image transformed by CLOSE and the image transformed by OPEN is contained in the original image. The DILATION and EROSION operations are also extensive and anti-extensive, respectively, if the center of the structuring element is located on a hit.

The OPEN and CLOSE operations also satisfy two more morphological properties:

- (1) The result of the operation is independent of the position of the center of the structuring element.
- (2) The operation is idempotent, which means that reapplying the OPEN or CLOSE to the resulting image will not change it.

An image unit means an identifiable segment of an image such as a word, number, character, glyph or other units that can be extracted reliably and have an underlying linguistic structure.

The term significant and its derivatives are used in this description to indicate the importance of particular characteristics of an image unit. An image unit with significant characteristics becomes a significant image unit in that it contains high value information which can be used for further processing of the document image. Significant characteristics of image units include a variety of classifiers such as length, width, location on a page of the document image, font, typeface and measurement by other parameters including, but not limited to: one or more cross-sections of a box (a cross-section being a sequence of ON or OFF pixels); a number of ascenders associated with an image unit; a number of descenders associated with an image unit; average pixel density in an image unit; a length of a topline contour of an image unit, including peaks and troughs; a length of a base contouring of the image units, including peaks and troughs; and the location of image units with respect to neighboring image units, e.g., vertical position and horizontal inter-image unit spacing.

Referring to FIG. 3, the method for detecting function words in a scanned document image without first converting the document image to character codes will be described. An image of a page of a document is scanned in step 302 and the image is segmented into image units in step 304 by using either a conventional image analysis techniques or by using first a technique to determine baselines of image units and then second a technique for providing bounding boxes around image units (see U.S. patent application Ser. No. 07/794,391 entitled "A Method of Deriving Wordshapes for Subsequent Comparison" by Huttenlocher et al.).

In step 306, a length and height of each image unit in the image is determined. Short image units are determined in step 308 as image units of no more than a predetermined number of characters, preferably three characters or less in length. In step 310, image units which are not short image units are deleted from the image. In step 312, the image is blurred or smeared in a horizontal direction although the image units are not smeared together. This can be accomplished for example by CLOSING the image with a hori-

zontal structuring element such as the structuring element of length 5 (i.e., 5 pixels) shown in FIG. 6. The length of the horizontal structuring element used to blur the x-height characters in the image is dependent upon the width of the character type being used. Furthermore, other configurations of structuring elements may be used in the CLOSING operation to obtain the same smearing effect. However, the most efficient and effective way to smear characters of x-height is to use a horizontal structuring element as described above.

A UNION of erosions is taken in step 314 of the image by using a set of ascender matching structuring elements such as those shown in FIGS. 4A-4F, and a set of descender matching structuring elements such as those shown in FIGS. 5A-5F. The UNION taken in step 314 provides optional noise elimination filtering, and the UNION will provide a seed from which to fill short image unit masks in a subsequent seed filling operation such as the fillClip operation of step 316. The UNION of step 314 acts on all image units remaining in the image (i.e., only short image units in this case) and since the UNION of erosions was taken using a set of ascender matching structuring elements and a set of descender matching structuring elements, the image units that will be filled are those containing ascender and/or descender characters, i.e., function words. The function words are identified in step 318 as those image units which are filled short image unit masks.

In step 320, a test occurs to determine whether a last page of the document has been scanned. If the last page has been scanned, then the method terminates at step 324, otherwise the page is incremented in step 322 and the incremented (next) page is scanned in step 302 whereupon the image (next page) is scanned and the previously described steps of the method are reiterated. Of course, all pages could be scanned and stored as bit map images in a memory prior to performing the function word identification procedures described above. Moreover, the image segmentation step can also be performed prior to performing this method and the segmented image stored in memory.

This is only one preferred method to perform the discrimination step 30 of FIG. 1. Using this method, the image units which have insufficient information content to be useful in evaluating the subject matter content of the document being processed are identified.

Next, in step 40, selected image units, e.g., the image units not discriminated in step 30, are evaluated, without decoding the image units being classified or reference to decoded image data, based on an evaluation of predetermined morphological (structural) image characteristics of the image units. The evaluation entails a determination (step 41) of the image characteristics and a comparison (step 42) of the determined image characteristics for each image unit with the determined image characteristics of the other image units.

One preferred method for defining the image unit image characteristics to be evaluated is to use the word shape derivation techniques disclosed in the copending U.S. patent application Ser. No. 07/794,391 filed concurrently herewith by D. Huttenlocher and M. Hopcroft, and entitled "A Method of Deriving Wordshapes for Subsequent Comparison," Published European Application No. 0543594, published May 26, 1993. As described in the aforesaid application, at least one, one-dimensional signal characterizing the shape of a word unit is derived; or an image function is derived defining a boundary enclosing the word unit, and the image function is augmented so that an edge function representing edges of the character string detected within the

boundary is defined over its entire domain by a single independent variable within the closed boundary, without individually detecting and/or identifying the character or characters making up the word unit.

More specifically, the above reference discloses a method for deriving, defining, and comparing words in terms of their shapes. It will, of course, be recognized that each element of the system may be many devices, or may simply be a program operated within a single device. The method will be described with reference to FIG. 7. Beginning with an input bitmap 710, a bitmap of an image is initially directed to a segmentation system 712, in which words, or character strings, or other multi-character units of understanding, will be derived. Initially, the image bitmap passes through skew detector 714, which determines the angle of orientation of text in the image. Using information about the orientation of the image, and the image itself, at text baseline processor 716, topline and baselines of the text are determined, so that upper and lower boundaries of lines of text within the image are identified.

At median filter 718, the function referred to as "blobify" is performed, which operates on the image so that each word group in a line may be treated as a single unit. As used herein, "word", "symbol string" or "character string" refers to a set of connected alphanumeric or punctuation elements, or more broadly, signs or symbols which together form a single unit of semantic understanding. It will be appreciated that these terms may also be used to refer to the images thereof. Such single units of understanding are characterized in an image as separated by a spacing greater than that which separates the elements, signs or symbols forming the unit. To the blobified image, a set of white lines are added at block 720, to clearly separate adjacent lines of text. The white lines are based on baseline determinations provided by processor 716. Using this information, i.e., the blobified words, which are clearly separated from adjacent words and words in adjacent lines, a bounding box is defined about the word at block 722, thereby identifying and enclosing the word.

Thereafter word shape signal computer 724 derives a word shape signal representing the individual words in the image, based on the original image and the bounding box determinations. This information is then available for use at a word shape comparator 726, for comparing word shape signals representative of known words from a word shape dictionary 728, with the as yet unidentified word shape signals. In an alternative embodiment word shape comparator 726 may be used to compare two or more word shapes determined from image 710. More importantly, word shape comparator 726 is not limited to the comparison of word shapes from unrecognized strings of characters to known word shapes. In a simplified context, comparator 726 is merely an apparatus for comparing one word shape against another to produce a relative indication of the degree of similarity between the two shapes.

In general, a method accomplishing this technique includes the following steps. Once orientation of the image is established and line spacing and word group spacing is established, each word can be surrounded by a bounding box. A reference line is then created extending through the character string image. The reference line may be a block having a finite thickness ranging from two-thirds of the x height to one-third of the x height, or in fact it may have a zero width. At the resolution of the image, the distance from the reference line to the upper edge of the text contour or bounding box is measured in a direction perpendicular to the reference line. Similarly, measurements may be made from the reference line to the lower bounding box edge or to the

text contour along the lower portion of the word, whichever is closer. Because the set of values derived computationally can be expressed in terms of position along the horizontal axis versus length, the signal can be considered a single independent variable or one dimensional signal. Either or both of these sets of values may be used to describe the word shape. Additionally, although possibly less desirable, it is well within the scope of this method to measure the distance of a perpendicular line drawn from the top of the bounding box or the bottom of the bounding box, to the first contact with the word or the reference line, as desired.

With a system and process for word shape derivation given, the method may also be considered mathematically. Considering image data $i(x,y)$, which in one common case could be an array of image data in the form of a bitmap, a character set is identified in one of many methods, perhaps as described above, which defines a boundary enclosing the selected symbol string within a subset of the array of image data. From $i(x,y)$, an edge signal $e(x,y)$, which represents the edges of $i(x,y)$ detected within the closed boundary, is derived. The edge signal is augmented by adding additional data to $i(x,y)$ so that $e(x,y)$ is a signal $e'(x,y)$ defined over its entire domain with respect to a single dimension or variable within the closed boundary. One, two, or more signals may be derived from $e'(x,y)$ which are each one dimensional signals $g(t)$, where g is a function of parameter t which is a reference frame dependent parameter.

It is important to realize that the mathematical process used for the derivation of the one dimensional signal is essentially reversible up to the information it contains, e.g., a bitmap may be reconstructed from the upper and lower bitmap contours. It will be noted that if the reference has a finite thickness and is therefore taken out of the image, that portion of the image is not identifiable, however, if it has a zero width the information still remains.

A recognition dictionary, or look up table of word shapes, can clearly be created through use of the described process. The process can be operated on using either scanned words as the source of the information, or in fact, they can be computer generated for a more "perfect" dictionary.

A detailed example using this method is disclosed in the U.S. patent application Ser. No. 07/794,391.

To demonstrate the process of the invention, at FIG. 10, a sample image, taken from a public domain source is shown, having several lines of text contained therein. FIG. 10 demonstrates approximately how the image would appear on the page of text, while FIG. 11, shows a scanned image of the page, which demonstrates an enlargement of the image of a bitmap that would present problems to known OCR methods. Looking at, for example, the image of the word 50a "practitioner" in the first line of the text image, it may be seen that several of the letters run together. Also, at the lower right hand portion of the image, circled and numbered 52, noise is present. Looking at the word "practitioner's", circled and numbered 54, the running together of a punctuation mark and a letter is further noted.

With reference again to FIG. 7, in one possible embodiment of the invention, skew detector 714, may be implemented using a general method for determining the orientation of the text lines in the image. This method looks at a small number of randomly selected edge pixels (defined as a black pixel adjacent to at least one white pixel), and for each edge pixel considers, at FIG. 12A, a number of lines, 56a, 56b, 56c being examples, extending from the pixel at evenly spaced angular increments over a specified range of angles. The edge pixels are selected randomly from the set of all image pixels by the function RandomEdgePixel()

(Appendix, page 243). FIGS. 12A (see lines 56a, 56b, 56c), 12B (see lines 58a, 58b, 58c) and 12C (see lines 60a, 60b, 60c) represent a series of increasingly smaller angular ranges over which the above mentioned technique is applied to illustrative edge pixels to accurately determine the angular orientation of the text within the image. Subsequent to finding edge pixels and defining the lines, skew detector 714 traces the path of each line, determining the lengths, in pixels, of strings of successive black pixels which are intersected by the line. Upon reaching the image boundary, an average black pixel string length is calculated by summing the lengths of the individual strings, and dividing the sum by the total number of distinct strings which were found. This operation is carried out for all the lines, thereby arriving at an average black pixel string length for each line extending from the selected edge pixel. These lengths are plotted on FIG. 12D as curve A, showing minima at approximately 0 and 3.14 radians. Curve A is a graphical representation of the summation/averaging function over each of a series of angled lines extending from the edge pixel, and spread over a range from 0 to 2π radians. Once a first minimum has been located, verification of the minimum (in the example, approximately 0 radians) is achieved by determining whether a second minimum exists at approximately π radians from the first minimum. Upon verifying the existence of a second minima (in the example, approximately 3.14 or π radians), a coarse skew angle is identified. Subsequently, it is necessary to more closely determine the skew angle of the text. This is accomplished by utilizing a number of lines which extend from a randomly selected edge pixel, where the lines differ by smaller angular increments, and the angular range is centered about the coarse skew angle. However, the fine skew angle may be determined by analyzing the total number of black pixels contained along a predetermined length of the lines. More specifically, the number of pixels over a unit distance are plotted as curve B on FIG. 12D, and the fine skew angle is determined by identifying the maxima of the curve. In other words, the point of the curve where the highest concentration of black pixels per unit line length exists, more accurately represents the angle of the text lines in the image. As shown by curve B, this results in a fine skew angle of approximately 0 radians, where the line intersects with the most black pixels along its length, and therefore is representative of the closest angle of orientation that needs to be determined.

Alternatively, the skew angle may be determined as indicated by the NewFine() function (Appendix, page 245), which determines the skew angle using multiple iterations of the procedure described with respect to the fine angle determination. As indicated by FIGS. 12A, 12B, and 12C, each iteration would also use lines covering an increasingly smaller angular range, until a desired skew angle accuracy is reached. In the implementation illustrated by FIGS. 12A, 12B, and 12C, the desired accuracy is achieved by a series of three iterations, each using a series of 180 distinct angles about the selected edge pixel.

In the next process step, illustrated in the graphs of FIG. 13A and FIG. 13B, text baseline processor 716 identifies the characteristic lines, upper topline and lower baseline, of each line of text. The process steps executed by text baseline processor 716 are illustrated in detail in FIGS. 14A and 14B. The histogram of FIG. 13A, shown to the left along the image, is derived by examining lines, at the resolution of the image, and oriented parallel to the skew orientation of the image, as defined by the previously determined skew angle. These parallel lines spanning the image are used to deter-

mine the number of black pixels intersected by each of the lines. Along lines passing through inter text line spaces, no black pixels should be intercepted, while along lines through the text, large numbers of black pixels should be intercepted.

More specifically, the function `BaseLines()`, (Appendix page 160), first finds the coordinates of a "main" line, block 142, constructed through the center of the image and perpendicular to the text lines, as determined by the skew angle passed to the function as shown by block 140. Next, Line Engine Procedure 144 is executed, where by proceeding along the main line from one end to the other, at a series of points along the main line, perpendicular branch lines are constructed which extend outwardly from the main line for a fixed distance, block 146. Along the branch lines, the number of black vertical edge pixels are counted, block 148, and the number of black pixels intersected by the lines are counted, block 150, and summed for the opposing pairs of lines, block 152. Black vertical edge pixels, as counted by block 148, are defined as black pixels having a white neighboring pixel at either the upper or lower neighboring pixel position. LineEngine() procedure 144 is repeated until all points, and associated branch lines, along the main line have been processed, as determined by decision block 154. An x-height value may be returned from this procedure, which will subsequently be used by the word shape computer 724.

Subsequently, the counts for all the branch lines are analyzed to determine the branch line pairs having the highest ratio of black vertical edge pixels to black pixels. In general, those lines having the highest percentages would correspond to lines passing along the upper and lower edges of the characters which form the text lines. As illustrated in the enlarged view of FIG. 13B, a definite distinction exists between those branch lines having a high vertical edge pixel ratio, line 82, and those having a low ratio, line 84. Application of a filter mask and comparison of the maximum peaks within the mask enables the identification of those lines which represent the text topline and baselines, for example, line 82. The process is implemented in the `maxFilter.c` module, beginning at line 57, the code for which is also incorporated in the `newBaselines.c` module at line 274, page 214. Baseline determination is described in further detail in a copending U.S. patent application, for a "Method for Determining Boundaries of Words in Text", Huttenlocher et al., U.S. patent application Ser. No. 07/794,392, which has been previously incorporated herein by reference. An additional test may also be applied to the histogram operation of step 150. This added test, a boolean test, may be used to assure that a minimum run of black pixels was detected during the analysis of the line. For example, a flag, which is cleared at the start of each branch line analysis, may be set whenever a series of five sequential black pixels are detected along the line. This test would assure that small noise or image artifacts are not recognized as baselines due to a high vertical edge pixel ratio.

As an alternative method, it is possible to utilize the total number of black pixels lying along the branch lines to determine the locations of the baselines. Using histogram curve BL, which represents the number of black pixels counted along the branch lines, it is possible to determine which branch lines have the most black pixel intersections. Applying a threshold of the maximum allows the determination of the upper and lower characteristic line pairs for each text line. Hence, the rising and falling portions of the histogram curve BL, constitute the characteristic lines of the text, and the threshold would be used to specifically identify the localized maxima surrounding an intervening minima,

thereby enabling identification of the baseline positions which would be used for further processing. More importantly, this alternative approach, illustrated as step 162, may be utilized to identify the upper and lower baselines of a baseline pair, based upon the slope of the BL histogram curve. It is important to note that there is little additional processing associated with the identification step as the histogram information was collected previously during step 150. Once the preliminary characteristic line or baseline pairs are identified, block 162, a verification step, block 164, is executed to verify that the baseline pairs are separated by more than a minimum distance, the minimum distance being established by calculating the average line pair separation for all line pairs in the image. After verification, the valid baseline information is stored by output block 166 for later use by the white line addition and segmentation blocks, 18 and 720, respectively.

An important advantage of these baseline determination methods, are that they are highly insensitive to noise or extraneous marks in the interline space. FIG. 15 shows the result of the baseline determination on the example image of the sample text, showing that baseline pair, baseline and topline B_u and B_l , respectively, have been located on the image, indicating those portions of the image in which a predominant portion of the text occurs. While some portions of the character ascender strokes are outside the baselines, no detriment to the remainder of the process is noted. Of course, a smaller threshold value might enable the system to capture more of the ascending strokes.

With reference again to FIG. 7 in conjunction with FIGS. 16 and 17, the next process step is a word group isolation step. A filter 718 is applied to a copy of the image which results in an image that tends to render the word into blobs distinguishable from one another. The filter is applied with a small window, to each area, to render as black those areas that are partly black. As shown in FIG. 16, the blobify function (Appendix page 165) first initializes mask variables which establish the mask size and angle, block 180, and then processes the upper scanline to initialize the data array, block 182. Median filtering is accomplished by sequentially moving the mask window through the image, blocks 184 and 186, and whenever the number of black pixels appearing in the window exceeds a threshold value, the target pixel, about which the window is located, is set to black. FIG. 17, which illustrates some examples of the filter process, has a mask window 200 placed over a portion of the image. For example, with a twenty percent threshold and a generally rectangular mask having twenty-one pixels, arranged at an angle approximately equal to the skew determined for the text, the result of filtering in window 200 would be the setting of pixel 204 to black. Similarly, window 206, which primarily lies within the intercharacter spacing between the pixel representations of the letters "r" and "o", would cause pixel 208 to be set to black. On the other hand, window 210, which lies in the region between word groups, would not have a sufficient number of black pixels present within the window to cause pixel 212 to be set to black. The size, shape and orientation of mask window 200 is optimized to reduce the filling in between text lines, while maximizing the fill between letters common to a single word.

As illustrated by FIG. 18, the result of the median filtering is that the relatively small spacing between characters in a word generally becomes inconsequential, and is filled with black pixels. Words become a single connected set of pixels, i.e., no white spaces completely separate characters in a single word. However, the relatively large spacing between character strings or between words, is a larger space outside

of the ability of the filter to turn into black, and therefore serves to distinguish adjacent symbol strings. With reference now to FIGS. 15 and 18, it can be seen that the first two words of the sample text, "A" and "practitioner" have been "blobified", as this process is referred to, so that, for example, the "p" of "practitioner" is no longer separated from the "r" of that word. (Compare, FIG. 11). Once again, despite the blobifying or blurring of characters, "A" and "practitioner" remain as discrete blobs of connected symbols, or words.

With reference again to FIG. 7, as an adjunct to this step, white line addition 720, superimposes upon the blobified image of FIG. 12 a series of white pixel lines to make certain that lines of text are maintained separately from adjacent lines of text (i.e., no overlapping of the filtered text lines). With reference to FIGS. 18 and 19, noting the circled areas 258 and 258', a combination of an ascender and descender has resulted in an interline merging of two words. The text line overlap illustrated in area 258 of FIG. 18 is exactly what is eliminated by superimposing the white lines on the blobified or filtered image.

This superposition of white lines operation, the outcome of which is illustrated by FIG. 19, is carried out by the process illustrated in FIG. 20 as executed in the DrawMiddleLines() function (Appendix page 233). Generally, white lines WL are added to the image, approximately halfway between adjacent baseline and topline pairs, to assure that there is no cross-text line blobifying. Once again, FIG. 19 shows the result of white line addition to the blobified image of FIG. 18.

Referring now to FIG. 20, white line addition block 720 begins by initializing variables in step 280 and subsequently reads in the topline location from the baseline information of the first text line. The topline information is discarded, block 282, and the next baseline and topline locations are popped from the storage stack or list, blocks 284 and 286, respectively. With respect to the image, this baseline-topline pair respectively represents the bottom and top of adjacent text lines. Next, at step 288, the point lying at the center of the pair is located to provide a starting point for the white lines which are drawn from the center of the image in an outward direction. The endpoints of the white lines are calculated in step 290, using the skew angle determined by skew detector 714 of FIG. 7. White lines are drawn or superimposed on the blobified image at step 292, and the process is continued until all text lines have been effectively separated, as controlled by test block 294.

With reference again to FIG. 7, as a result of the blobify or median filtering, the position of bounding boxes about each connected set of pixels formed in the blobify step may be determined. Bounding boxes are placed only about those connected components or words that are in a text line lying between the superimposed white lines. The bounding boxes are placed at the orientation of the text line, by identifying the extreme points of each group of connected pixels in the direction of the text line, and in the direction orthogonal to the text line, as opposed to the image coordinate system. This operation is performed by the function FindBorders(), (Appendix, page 172). Generally, the FindBorders function steps through all pixels within the image to find the bounding boxes of the connected characters (Paint Component), to determine the coordinates of the upper left corner of each box, as well as the length and width of the box.

Referring now to FIGS. 21A and 21B, which detail the FindBorders() procedure, segmentation step 1022 begins by placing a white border completely around the filtered image, step 1300. This is done to avoid running outside the edge of the array of image pixels. Next, pixel and line counters, x and y, respectively, are initialized to the first pixel location

inside the border. Calling the ReadPixel procedure, block 1304, the pixel color (black or white) is returned and tested in block 1306. If the pixel is white, no further processing is necessary and processing would continue at block 1322. Otherwise, the PaintComponent() procedure (Appendix, page 171) is called and begins by storing the location of the black pixel in a queue, block 1308. Subsequently, in a copy of the image, the pixel is set to white and the boundaries of the box, surrounding the connected pixels or components, are updated, blocks 1310 and 1312, respectively. Next, adjoining black pixels are set to white, block 1314, and the locations of the black pixels are added to the end of the queue, block 1316. At block 1318 the queue pointers are tested to determine if the queue is empty. If not empty, the next pixel in the queue is retrieved, block 1320, and processing continues at block 1312. Otherwise, if the queue is empty, all of the connected black pixels will have been set to white and the box boundaries will reflect a box which encompasses the connected components. Subsequently, the boundaries of the box which encompasses the word segment are verified and may be adjusted to an orthogonal coordinate system oriented with respect to the skew of the text lines, block 1322.

It will no doubt be apparent here that while finding each text line is an integral part of the described method, and serves to make the present embodiment more robust, other methods of deriving the information acquired by that step are possible. The primary use of the text line finding function is a) to determine x-height, and b) define the white line addition, for separating interline blobs. Certainly this step may be removed, with a sacrifice in robustness, or other means of deriving the necessary information may be available.

The looping process continues at block 1324 which checks pixel counter x to determine if the end of the scanline has been reached, and if not, increments the counter at block 1326 before continuing the process at block 1304. If the end of the scanline has been reached, pixel counter x is reset and scanline counter y is incremented at block 1328. Subsequently, block 1330 checks the value of scanline counter y to determine if the entire image has been processed. If so, processing is completed. Otherwise, processing continues at block 1304 for the first pixel in the new scanline.

Thus, as shown in FIG. 22, for the word "practitioner" the extremities of the connected character image define the bounding box. Once bounding boxes have been established, it is then possible at this step, to eliminate noise marks from further consideration. Noise marks are determined: 1) if a bounding box corner is outside the array of image pixels (Appendix, page 171); 2) if a box spans multiple text lines in the array (Appendix 229), or lies completely outside a text line; 3) if boxes are too small compared to a reference ϵ , in either or both longitudinal or latitudinal directions, and accordingly are discarded. Noise marks 70a and 72 and others will not be considered words. The OnABaseline() function (Appendix, page 229) is an example of a function used to eliminate those boxes lying outside of the baseline boundaries.

With reference to FIG. 7, at word shape computer 724, a signal representing the image of a word, or at least a portion thereof, now isolated from its neighbors, is derived. The derived signal is referred to as a word shape contour. The shape contour for each word is determined using the MakeShell() function (Appendix, page 228). As illustrated in FIG. 23A, this function first moves along the top of each bounding box, and starting with each pixel location along the top of the box, scans downward relative to the page

orientation, until either a black pixel, or the bottom of the box, is reached. A record of the set of distances d between the top of the box and the black pixel or box bottom is maintained. The set of distances d , accumulated over the length of the box, constitutes the top raw contour of the word shape. Subsequently, a bottom raw contour is produced in a similar manner as illustrated in FIG. 23B, for the same word depicted in FIG. 23A, by sequentially moving across the bottom of the box, and looking in an upwards direction, for either the first black pixel or the top of the bounding box.

With reference now to FIG. 25, at block 100 which preferably operates on the actual image as opposed to the filtered image, which could be used in this step, one or more reference lines are established through each word. In other terms, the data representing the symbol string is augmented, so that it is defined over the range of the symbol string. In one embodiment, a blackout bar, which may have a finite thickness or a zero thickness is constructed through the word, preferably having an upper limit or reference line at approximately two thirds of the x height, and a lower limit or reference line at approximately one-third of the x height (which was determined at the baseline determination step). At contour calculation 102, a set of measurements is derived, for the distance d between the upper or lower edge of the bounding box, and the word, or the nearer of the reference line's closer edge of the black out bar. The calculation's measurements are made at the resolution of the image. With reference to FIG. 26A, where the calculation's measurements are illustrated pictorially, it can be seen that the reference lines serve to allow the signal that will ultimately be derived from this step to be defined at every sampling position over the length of the word. In a preferred embodiment, the calculation's measurements of d are actually generated from the contour data derived in accordance with FIGS. 23A, 23B previously collected, and are adjusted to limit the distance d with either the upper or lower edge of the blackout bar as indicated. In the embodiment shown in FIG. 26A, measurements are made from the upper line of the bounding box to the upper reference line of the word, although this is not a requirement. Thus, for example, the measurement could alternatively be made from the reference line to either the upper or lower bounding line, or the character. FIG. 26B better shows how the set of measurements is used to form the signal output from block 104. The contour is represented as a set of measurements distance d , relative to the reference line. Measurement d is therefore derived from the measurements shown in FIG. 26A, which designate the stopping point of line d , and the known position of the black out bar. Calculating the distance relative to the reference line enables scaling of the word shape contours to a common x height, thereby facilitating any subsequent comparison of the shapes. Accordingly, the distances d represent a measurement from the reference line or blackout bar to the outer limits of the letter, and in the absence of a letter, provide a zero measurement. These measurement might be derived directly, but the proposed indirect methods appear easier to implement. FIGS. 26C and 26D show that the sets of d values can be plotted on a graph to form a one dimensional signal or curve representing the word shape. Details of the contour determination are contained in the function StoreOutlinePair() beginning in the Appendix at page 255. FIG. 24 is an image of the contour locations as established for the text sample of FIG. 10. It is important to note the informational content of FIG. 24, where, for the most part, it is relatively easy to recognize the words within the passage by their contours alone.

In studies of the information delivered by the appearance of English language words, it has been determined that in a majority of cases, words can be identified by viewing only approximately the top third of the image of the word. In other words, the upper portion of the word carries with it much of the information needed for identification thereof. In a significant portion of the remainder of cases, words that are unidentifiable by only the upper third of the image of the word, become identifiable when the identification effort includes the information carried by the lower third of the image of the word. A relatively small class of words requires information about the middle third of the word before identification can be made. It can thus be seen that a stepwise process might be used, which first will derive the upper word shape signal or contour, second will derive the lower word shape signal or contour, and thirdly derive a word shape signal central contour (from the reference line towards the word or bounding box), in a prioritized examination of word shape, as required. In the examples of FIG. 26A, 26B, and 26C, the word "from" is fairly uniquely identifiable from its upper portion only. In the examples of FIG. 27A, 27B, 27C and 27D, the word "red" is less uniquely identifiable from its upper portion, since it may be easily confused with the word "rod", and perhaps the word "rad". While the lower portion of the letter "a" may distinguish "red" and "rad", it is doubtful that the lower portion of the letter "o" will distinguish the words "red" from "rod". However, the central portions of "red", "rad", and "rod" are quite distinct.

The determined morphological image characteristic(s) or derived image unit shape representations of each selected image unit are compared, as noted above (step 42), either with the determined morphological image characteristic(s) or derived image unit shape representations of the other selected image units (step 42A), or with predetermined/user-selected image characteristics to locate specific types of image units (step 42B). The determined morphological image characteristics of the selected image units are advantageously compared with each other for the purpose of identifying equivalence classes of image units such that each equivalence class contains most or all of the instances of a given image unit in the document, and the relative frequencies with which image units occur in a document can be determined, as is set forth more fully in the copending U.S. patent application Ser. No. 07/795,173 filed concurrently herewith by Cass et al., and entitled "Method and Apparatus for Determining the Frequency of Words in a Document without Document Image Decoding." Image units can then be classified or identified as significant according to the frequency of their occurrence, as well as other characteristics of the image units, such as their length. For example, it has been recognized that a useful combination of selection criteria for business communications written in English is to select the medium frequency word units.

The method for determining the frequency of words without decoding the document is shown in FIG. 8. The image is segmented into undecoded information containing image units (step 820) by using the method described above or by finding word boxes. Word boxes are found by closing the image with a horizontal SE that joins characters but not words, followed by an operation that labels the bounding boxes of the connected image components (which in this case are words). The process can be greatly accelerated by using 1 or more threshold reductions (with threshold value 1), that have the effect both of reducing the image and of closing the spacing between the characters. The threshold reduction(s) are typically followed by a closing with a small horizontal SE. The connected component labeling operation

is also done at the reduced scale, and the results are scaled up to full size. The disadvantage of operating at reduced scale is that the word bounding boxes are only approximate; however, for many applications the accuracy is sufficient. The described method works fairly well for arbitrary text fonts, but in extreme cases, such as large fixed width fonts that have large inter-character separation or small variable width fonts that have small inter-word separation, mistakes can occur. The most robust method chooses a SE for closing based on a measurement of specific image characteristics. This requires adding the following two steps:

- (1) Order the image components in the original or reduced (but not closed) image in line order, left to right and top to bottom.
- (2) Build a histogram of the horizontal inter-component spacing. This histogram should naturally divide into the small inter-character spacing and the larger inter-word spacings. Then use the valley between these peaks to determine the size of SE to use for closing the image to merge characters but not join words.

After the bounding boxes or word boxes have been determined, locations of and spatial relationships between the image units on a page are determined (step 825). For example, an English language document image can be segmented into word image units based on the relative difference in spacing between characters within a word and the spacing between words. Sentence and paragraph boundaries can be similarly ascertained. Additional region segmentation image analysis can be performed to generate a physical document structure description that divides page images into labelled regions corresponding to auxiliary document elements like figures, tables, footnotes and the like. Figure regions can be distinguished from text regions based on the relative lack of image units arranged in a line within the region, for example. Using this segmentation, knowledge of how the documents being processed are arranged (e.g., left-to-right, top-to-bottom), and, optionally, other inputted information such as document style, a "reading order" sequence for word images can also be generated. The term "image unit" is thus used herein to denote an identifiable segment of an image such as a number, character, glyph, symbol, word, phrase or other unit that can be reliably extracted.

Advantageously, for purposes of document review and evaluation, the document image is segmented into sets of signs, symbols or other elements, such as words, which together form a single unit of understanding. Such single units of understanding are generally characterized in an image as being separated by a spacing greater than that which separates the elements forming a unit, or by some predetermined graphical emphasis, such as, for example, a surrounding box image or other graphical separator, which distinguishes one or more image units from other image units in the document image. Such image units representing single units of understanding will be referred to hereinafter as "word units."

A discrimination step 830 is next performed to identify the image units which have insufficient information content to be useful in evaluating the subject matter content of the document being processed by using the technique described above.

Next, in step 840, selected image units, e.g., the image units not discriminated in step 830, are evaluated, without decoding the image units being classified or reference to decoded image data, based on an evaluation of predetermined image characteristics of the image units. The evaluation entails a determination (step 841) of the image char-

acteristics and a comparison (step 842) of the determined image characteristics for each image unit with the determined image characteristics of the other image units.

One preferred method for defining the image unit morphological image characteristics to be evaluated is to use the word shape derivation techniques previously discussed. At least one, one-dimensional signal characterizing the shape of a word unit is derived; or an image function is derived defining a boundary enclosing the word unit, and the image function is augmented so that an edge function representing edges of the character string detected within the boundary is defined over its entire domain by a single independent variable within the closed boundary, without individually detecting and/or identifying the character or characters making up the word unit.

The determined image characteristic(s), e.g., the derived image unit shape representations of each selected image unit are compared, as noted above (step 841), with the determined image characteristic(s)/derived image unit shape representations of the other selected image units for the purpose of identifying equivalence classes of image units (step 850), such that each equivalence class contains most or all of the instances of a given word in the document. The equivalence classes are thus formed by clustering the image units in the document based on the similarity of image unit classifiers, without actually decoding the contents of the image units, such as by conversion of the word images to character codes or other higher-level interpretation. Any of a number of different methods of comparison can be used. One technique that can be used, for example, is by correlating the raster images of the extracted image units using decision networks, such technique being described for characters in a Research Report entitled "Unsupervised Construction of Decision networks for Pattern Classification" by Casey et al., IBM Research Report, 1984, herein incorporated in its entirety.

Depending on the particular application, and the relative importance of processing speed versus accuracy, for example, comparisons of different degrees of precision can be performed. For example, useful comparisons can be based on length, width or some other measurement dimension of the image unit (or derived image unit shape representation e.g., the largest figure in a document image); the location of the image unit in the document (including any selected figure or paragraph of a document image, e.g., headings, initial figures, one or more paragraphs or figures), font, typeface, cross-section (a cross-section being a sequence of pixels of similar state in an image unit); the number of ascenders; the number of descenders; the average pixel density; the length of a top line contour, including peaks and troughs; the length of a base contour, including peaks and troughs; and combinations of such classifiers.

One way in which the image units can be conveniently compared and classified into equivalence classes is by comparing each image unit or image unit shape representation when it is formed with previously processed image units/shape representations, and if a match is obtained, the associated image unit is identified with the matching equivalence class. This can be done, for example, by providing a signal indicating a match and incrementing a counter or a register associated with the matching equivalence class. If the present image unit does not match with any previously processed image unit, then a new equivalence class is created for the present image unit.

Alternatively, as shown (step 50) the image units in each equivalence class can be linked together, and mapped to an equivalence class label that is determined for each equivalence class. The number of entries for each equivalence class can then be merely counted.

Thus, after the entire document image, or a portion of interest, has been processed, a number of equivalence classes will have been identified, each having an associated number indicating the number of times a image unit was identified having similar morphological characteristics, or classifiers, thus determining the image unit frequency.

It will also be appreciated that the selection process can be extended to phrases comprising identified significant image units and adjacent image units linked together in reading order sequence. The frequency of occurrence of such phrases can also be determined such that the portions of the source document which are selected for summarization correspond with phrases exceeding a predetermined frequency threshold, e.g., five occurrences. A preferred method for determining phrase frequency through image analysis without document decoding is disclosed in copending U.S. patent application Ser. No. 07/774,555 filed concurrently herewith by Withgott et al., and entitled "Method and Apparatus for Determining the Frequency of Phrases in a Document Without Document Image Decoding."

It will be appreciated that the specification of the image characteristics for titles, headings, captions, linguistic criteria or other significance indicating features of a document image can be predetermined and selected by the user to determine the selection criteria defining a "significant" image unit. For example, titles are usually set off above names or paragraphs in boldface or italic typeface, or are in larger font than the main text. A related convention for titles is the use of a special location on the page for information such as the main title or headers. Comparing the image characteristics of the selected image units of the document image for matches with the image characteristics associated with the selection criteria, or otherwise recognizing those image units having the specified image characteristics permits the significant image units to be readily identified without any document decoding.

Any of a number of different methods of comparison can be used. One technique that can be used, for example, is by correlating the raster images of the extracted image units using decision networks, such technique being described in a Research Report entitled "Unsupervised Construction of Decision networks for Pattern Classification" by Casey et al., IBM Research Report, 1984, herein incorporated in its entirety.

Preferred techniques that can be used to identify equivalence classes of word units are the word shape comparison techniques disclosed in U.S. patent application Ser. Nos. 07/796,119 and 07/795,169, filed concurrently herewith by Huttenlocher and Hopcroft, and by Huttenlocher, Hopcroft and Wayner, respectively, and entitled, respectively, "Optical Word Recognition By Examination of Word Shape," Published European Application No. 0543592, published May 26, 1993, and "Method for Comparing Word Shapes."

For example, U.S. patent application Ser. No. 07/795,169 discloses, with reference to FIG. 7, one manner in which a comparison is performed at word shape comparator 726. In one embodiment, the comparison is actually several small steps, each of which will be described. With reference to FIG. 28, generally, the two word shape signals, one a known word, the other for an unknown string of characters are compared to find out whether they are similar. However, in this case, signal R is the upper contour of the word "red", while signal F is the upper contour of the word "from". Actually, relatively few signals could be expected to be exactly identical, given typical distinctions between character fonts, reproduction methods, and scanned image quality. However, the word shape signals to be compared may be

scaled with respect to one another, so that they have the same x-heights. This is achieved by determining the x-height of the pair of word shape contours to be compared. Once determined, the ratios of the x-heights are used to determine a scale factor to be applied to one of the contours. As the x-height is a characteristic measurement for fonts, it is used to determine the scaling factor in both the horizontal and vertical directions. An example of the scaling operation is found in the fontNorm.c file beginning at line 172, where the StoreOutlinePair() function carries out the scaling operation in both the x and y, horizontal and vertical, directions. Alternatively, the shape signals may be compared without normalization and a weighing factor imposed upon the portion of the measured difference due to the unequal lengths. Furthermore, the amplitude or height of the signals has been normalized to further reduce the impact of the font size on the word shape comparison.

Referring next to FIGS. 29A-29C, which illustrate details of the ascender/descender normalization operation, each of the shape signals are normalized based upon a common relationship between the ascender and descender heights and the x-height of the text characters. As illustrated, the actual ascender heights of characters printed with supposedly similar font size, or what is now an appropriately scaled font size, may be slightly different. This occurs as a result of type faces or fonts which are small on body or large on body, implying that similar characters exhibit variations in height across fonts that are the same size, for example 24 point fonts. As an illustration, distance d_1 in FIG. 29A represents the difference in ascender height for two occurrences of the letter "h." Likewise, distance d_2 illustrates a similar difference between the heights of the letter "f" in FIG. 29B. As illustrated in FIG. 29C, the typical character may be broken into three sections, ascender portion 390, x-height portion 392, and descender portion 394. In addition, the relative heights of these sections are illustrated as c, a, and b, respectively. Again, the normalization operation applied to the shape contours is found in the fontNorm.c module, beginning at page 183 of the Appendix. Applying the operations described with respect to StoreOutlinePair() function, page 255 of the Appendix, the areas of the contour lying above the x-height are scaled as follows:

$$f(t) = \frac{1.5}{a+c} \cdot f(t)$$

Similarly, the descenders are scaled by the following equation:

$$f(t) = \frac{1.5}{a+b} \cdot f(t)$$

where, in both cases, the value used in the numerator (1.5) is arrived at based upon observation of the relationship between ascender or descender heights and the x-height. Also included within the StoreOutlinePair() function is an operation to remove the portions of the contours which do not represent portions of the text string. These regions lie at the ends of the bounding boxes illustrated in FIG. 22. For example, the box surrounding the word "practitioner" in FIG. 22 can be seen to extend beyond the actual word image. As further illustrated at the ends of the word "from" in FIGS. 26A-26D, the contour does not contain useful information. By removing these regions from the contour shape, less error will be introduced into the comparison operations.

Subsequent to the normalization operation, standard signal processing steps can be used to determine the similarity or dissimilarity of the two signals being compared. Alternatively, the following equation may be used:

$$\Delta_{string} = \sqrt{\int_0^1 (f(x) - g(x))^2 dx}$$

where

Δ_{string} is the difference value between the two signals;

$f(x)$ is the known signal; and

$g(x)$ is the unknown signal.

In a simple determination, the difference could be examined and if it is close to zero, such would be indicated that there would be almost no difference between the two signals. However, the greater the amount of difference, the more likely that the word was not the same as the word to which it was being compared.

It is important to note that the embodiments described herein, as supported by the code listings of the Appendix, compare the word shape contours using the upper and lower contours for each word in conjunction with one another. This is an implementation specific decision, and is not intended to limit the invention to comparisons using only the top and bottom contours in conjunction with one another. In fact, sufficient information may be contained within the upper contours alone so as to significantly reduce the requirements for a comparison of the lower contours, thereby saving considerable processing effort.

The steps of this simplified comparison method, as first contemplated, are illustrated in FIG. 30. Beginning at step 410, the contour for the first word shape is retrieved from memory, and subsequently, the second word shape is retrieved by step 412. Next, the centers of gravity of the word shapes, defined by the upper and lower contours, are determined and aligned, step 414. The purpose of this step is to align the centers of the word contours to reduce the contour differences that would be attributable solely to any relative shift between the two sets of contours being compared. The center of gravity is determined by summing the areas under the curves (mass) and the distances between the contours (moments) which are then divided to give an indication of the center of gravity for the upper and lower contour pair. Once determined for both sets of contour pairs, the relative shift between the pairs is determined, step 416, and the contours are shifted prior to calculating the difference between the contours. The shifting of the contours is necessary to reduce any error associated with the establishment of the word shape boundaries and computation of the word shapes at block 724 of FIG. 7. Step 418 handles those regions lying outside the overlapping range of the shifted contour pairs, determining the difference against a zero amplitude signal in the non-overlapping regions. This is done by summing the squared values of the upper and lower contours at the non-overlapping ends of the contours. Subsequently, the overlapping region of the contours are compared, step 420. The difference in this region is determined as the sum of the squared differences between the upper curves and the lower curves, as shown in the function L2Norm() on page 100 of the Appendix. Next, the values returned from steps 418 and 420 are added to determine a sum of the differences over the complete range defined by the shifted contours. This value may then be used as a relative indication of the similarity between the contour pairs for the two word shapes being compared.

An alternative to the center-of-gravity comparison method, uses a signal processing function known as time warping, as described in the article "Performance Tradeoffs in Dynamic Time Warping Algorithms for Isolated Word Recognition", by Myers, Rabiner, and Rosenberg, IEEE

Transactions on Acoustics, Speech, and Signal Processing, Vol. ASSP-28, No. 6, December 1980, and the book, "Time Warps, String Edits, and Macromolecules: The Theory and Practice of Sequence Comparison", by Sankoff and Kruskal, Addison-Wesley Publishing Company, Inc., Reading, Mass., 1983, Chapters 1 and 4, and may be used to provide for compression and expansion of points along the contours until the best match is made. Then a score is derived based on the amount of difference between the contours being compared and the stretching required to make the contours match. Once again, the score provides a relative indication of the match between the two signals being compared.

Referring now to FIG. 31, which depicts the general steps of the dynamic warping method, the method relies on the use of a difference array or matrix to record the distances between each point of the first contour and points of the contour to which it is being compared. As illustrated in the figure, and detailed in the code listings contained in the Appendix, the process is similar for all of the measures which may be applied in the comparison.

First, the organization of the code is such that a data structure is used to dynamically control the operation of the various comparison functions. The structure DiffDescriptor, the declaration for which is found on page 9 of the Appendix (see diff.h), contains variables which define the measure to be applied to the contours, as well as, other factors that will be used to control the comparison. These factors include: normalization of the contour lengths before comparison; separate comparisons for the upper and lower contours; a centerWeight factor to direct the warping path; a bandwidth to constrain the warp path; a topToBottom ratio which enables the top contour comparison to be weighted more or less with respect to the bottom contour comparison; and a hillToValley ratio to selectively control weighing the contour differences when an unknown contour is being compared to a known or model word shape contour. Interpretation of the various factors is actually completed in the diff2.c module at page 56 of the Appendix, although descMain.c at page 49 provides an illustration of the interpretation of the factors.

In general, each measure implements a comparison technique, however, each is optimized for a specific type of dynamic comparison, for example, a slope limited dynamic warp having a non-unitary centerweight and a topToBottom weight greater than one. The first level of selection enables the use of a slope-constrained warping function for comparison, an unconstrained warp, or a simple, non-warped, comparison. Within both of the warp comparison methods, there are both separate comparison functions, where the top and bottom contours are warped independently, and parallel comparison functions, where the warp is applied to both the top and bottom contours simultaneously. Specific details of the comparison functions are generally contained within the newMatch.c file beginning at page 101 of the Appendix.

In the general embodiment, the dynamic warping process starts by allocating space for the path/distance array, step 450, which will hold the distance values generated during the comparison and warping of one word shape contour with respect to another. After allocating space, the border regions of the array must be initialized as the process used by all the warping measures is an iterative process using data previously stored in the array for the determination of the cumulative difference between the contours. At step 452, the array borders are initialized. Initialization of the first row of the array entails the determination of the square of the difference between a first point on the first contour and each point on the second contour. Subsequent to border initial-

ization, the column and row index values, L1 and L2, respectively, are reset to 1 to begin processing the individual, non-border, points along the contours.

Processing of the contours proceeds at steps 458 through 464, where the difference in distance between each point along the second contour, with respect to a point on the first contour is calculated. Moreover, this difference, or distance, is calculated and then summed with a previously determined difference value. In addition, some of the previously determined difference values may be weighted differently, for example, in one embodiment weights of the difference values along the array diagonal may be modified by a centerWeight weighing factor. As an illustration, the operation of the NewMatch() function, beginning at line 106 on page 103, at first, the distance (rest) is calculated as the sum of the squares of the differences between a point on the first contour and a point on the second contour, over the upper and lower contours, where the top contour difference is weighted by the topToBottom variable. This distance (rest) is used in subsequent iterations to determine the horizontal, vertical and diagonal difference values in the loop beginning at line 137 on page 103. To determine each of these values, the current distance value, represented by rest, would be added to the previous values in the down, left, and down-left array positions, the down-left position value being the diagonal position which is weighted by the centerWeight factor as previously described. Referring to FIG. 32A, which illustrates the positional relationship between a previously determined value X, at array location 502, and subsequent array locations, the value X might be added to the difference values of subsequent locations to accumulate the total difference. calculations is shown. When calculating the difference value for array location 504, the value in location 502 would be used as the down value. Similarly, when calculating the value in location 506, the value of location 502 would be used as the center-weighted down-left, or diagonal, value. After calculating the three difference values, steps 458, 460, and 462, the process continues by selecting the smallest of the three values, step 464, for insertion into the current array position, step 466. As illustrated in the Appendix at line 144 of page 103, the FMin() function from page 101 returns the minimum of the three values previously calculated, the value being inserted into the storage array pointed to by pointer dc.

Subsequently, the process illustrated in FIG. 31 continues by determining the differences between the point on the first contour, represented by L1, to points on the second contour, represented by L2. Decision step 468 controls the iterative processing of the points along the second contour by testing for the end of the contour, or swath. In the implementation shown in the Appendix, the index variables i and j are used in place of L1 and L2 to control the difference calculation loops. As indicated in the code for the NewMatch function beginning on page 102 of the Appendix, the swath is referred to as the bandwidth, and is determined by a desired bandwidth which is adjusted for the slope defined by the contour lengths (see page 102, lines 83-89). If no limit has been reached, processing for the next point would continue at step 458 after the value of L2 was incremented at step 470. Similarly, decision step 472 controls the processing of each point along the first contour, in conjunction with incrementing step 474. Once all the points have been processed with respect to one another, as evidenced by an affirmative response in step 472, the relative difference score, best score, is contained in the farthest diagonal position of the array (L1, L2). Subsequently, the value determined at step 476 is returned as an indication of the dynamically warped difference between the contours being compared.

The code implementation found in the NewMatch() function on page 103 of the Appendix has optimized the execution of the aforedescribed warping process by reducing the large two-dimensional array to a pair of linear arrays which are updated as necessary. Due to this modification, the minimum difference, or best score, for the warp comparison value is found in the last location of the one-dimensional array. Furthermore, the final difference value, dc, may be subsequently normalized to account for the length differences between the two sets of contours being compared. Finally, such a value might subsequently be compared against a threshold or a set of similarly obtained difference values to determine whether the contours are close enough to declare a match between the words, or to determine the best match from a series of word shape comparisons.

In yet another embodiment, the dynamic time warping process previously described may be altered to compare the difference values contained in the difference array to a threshold value on a periodic basis. Upon comparison, the process may be discontinued when it is determined that sufficient difference exists to determine that the contours being compared do not match one another, possibly saving valuable processing time. Moreover, the sequential operation of word shape comparator 726 might be done in conjunction with sequential output from word shape computer 724, thereby enabling the parallel processing of a textual image when searching for a keyword.

Having described a basic implementation of the dynamic warping comparison measures, the distinctions of the other dynamic warp comparison methods included in the Appendix and the application of the control factors previously mentioned will be briefly described to illustrate the numerous possible embodiments of the present invention. First, the method previously described may also be implemented with the slope of the warp path being constrained as it moves across the array. Details of the implementation are found in the SlopeCMatch() function beginning on page 111 of the Appendix. This measure is further illustrated graphically in FIG. 32B, where the value of array location 512, X, may be added to only the three subsequent array locations shown. For example, X may be added to array location 514, when considered as the d2L1 value for location 514. The nomenclature used for the variable names, and followed in the figure, is as follows: d2L1 refers to the array location which is down 2 rows and left one column, d1L1, refers to the lower left diagonal array location, and d1L2 refers to the array location that is down one column on left 2 rows from the current array location. In a similar manner, X may be added as the d1L2 value for the calculation of the cumulative difference value for array location 516.

As is apparent from a comparison of FIGS. 32A and 32B, the slope constrained warping measure limits the warping path which can be followed during the generation of the cumulative difference value. The reason for implementing such a constraint is to prevent the warping process from removing, or compressing, a large area of one of the two contours being compared, without imposing a significant "cost" to such a compression.

Next, the method previously described with respect to the parallel warping process may also be implemented on only one pair of contours at a time, for example, the upper contours of two word shapes. The functions SepMatch() and SepCMatch(), as found in the Appendix on pages 104 and 113, respectively, implement the separate matching measure in both the non-slope-constrained and slope-constrained fashions previously described. In general, these measures separately calculate the difference between the top or bottom

contours of a pair of wordshapes. The general implementation indicated for the measures in the code shows that these measures are typically used sequentially, first determining the warped difference for the top contours, and then adding to it the warped difference from the bottom contour comparison, resulting in a total difference for the wordshapes.

By carrying out the comparison methods described in a "piece-wise" cascaded fashion, further processing benefits may also be derived. More specifically, cascaded comparison would entail, first, utilizing the upper contours of the words being compared to identify a word, or at least narrow the set of possible alternatives and, second, using the lower contour comparison to provide complete identification. It is believed that such an approach to word shape comparison operation 726 would considerably reduce processing time spent on identifying unknown word shapes by comparison to a dictionary of known word shapes, 728, as illustrated in FIG. 7. Important to the cascaded comparison, is the constraint that the top and bottom warps applied to the contours must be relatively equivalent. This requirement arises from the fact that the upper and lower curves have a relationship to a common word, and if this relationship is not maintained during the warp analysis, the accuracy of the comparison will be compromised.

Alternatively, the dynamic warping technique may be applied as described, with the addition of a function suitable for accumulating the relative warp applied to the upper and lower curves in achieving the best match. For example, when a known, non-italicized word shape is compared to an unknown word shape, a shift in the warp applied to the upper curve relative to the lower curve could be indicative of an italicized word, however, the length of the warped region will remain the same for the top and bottom warps. Such a technique may prove useful in the identification of important words within a larger body of text, as these words are occasionally italicized for emphasis.

One of the control factors which has not been previously described is the bandwidth factor. As implemented, the bandwidth factor controls the relative width of the signal band in which the warping signal will be constrained. More specifically, the band width limitation is implemented by defining a region about the array diagonal in which the warp path which traverses the array is constrained. The constraint is implemented by assigning large values to those areas outside of the band width, so as to make it highly unlikely that the path would exceed the constraint.

Another factor which was briefly mentioned is the top-ToBottom factor. When applied, the value of this variable is used to weight the difference value determined for the top contour warping process. Therefore, use of a number greater than one, will cause the upper contour difference to be weighted more heavily than the lower contour difference. A very large number would effectively eliminate the lower contour difference completely and, likewise, a zero value would eliminate the upper contour difference completely. This factor is generally considered important to enable the upper contour to be weighted in proportion to its information content, as it generally carries more information regarding the word than does the lower contour.

The hillToValley ratio is a variable which is usually applied in situations when a known, or model, set of word shape contours is being compared against a set of word shape contours from an unknown image. In exercising this option, the model set of contours is passed as the comparison measure functions, for example, NewMatch() on page 102 of the Appendix. When determining the difference between points on the contours, the comparison functions commonly

call the function SquareDifference() on page 101 of the Appendix to determine the sum of the squared difference. SquareDifference() applies the hillToValley ratio to the squared difference whenever it determines that the value of the model contour is less than the contour being compared. The result of applying a hillToValley value greater than one is that the relative "cost" of the difference when the model contour is less than the target contour is smaller than the same difference when the model contour is greater than the target contour. The basis for this type of weighing is that when comparing against a model contour, the comparison should treat those areas of the target contour that are subject to being "filled in" during a scanning or similar digitizing operation with less weight than regions not likely to be filled in, as evidenced by contour positions below the model contour. For instance, the regions where ascenders and descenders meet the body of the character are likely to be filled in during scanning, thereby causing the target contour to have a gradual contour in those regions, whereas the model contour would most likely have a defined peak or valley in these regions. Hence, the contour value of the model would be less than the contour value of the target, even though the characters may have been identical. Therefore, the hillToValley variable attempts to minimize the impact to the calculated difference value over these regions.

It is important to note that the aforescribed measures and control factors allow the comparison measures to be conducted in numerous permutations. However, the flexibility which these measures permit is intended to enhance the applicability of the comparison process, so that when information is known about a particular word shape contour, for example, a model contour generated from a computer generated character font, the measures may place reliance on that information to make the comparisons more robust.

The mathematical explanation of the word shape derivation process suggests that alternative methods of deriving the word shape signal exist. Some possible alternatives are the establishment of the one dimensional signal using an alternative coordinate scheme, for example polar coordinates. Another possibility is generation of signal $g(t)$, where $g(t)$ represents the direction from each contour point to the succeeding contour point, where t would represent the point number.

Depending on the particular application, and the relative importance of processing speed versus accuracy, for example, comparisons of different degrees of precision can be performed. For example, useful comparisons can be based on length, width or some other measurement dimension of the image unit (or derived image unit shape representation, e.g., the largest figure in a document image); the location or region of the image unit in the document (including any selected figure or paragraph of a document image, e.g., headings, initial figures, one or more paragraphs or figures), font, typeface, cross-section (a cross-section being a sequence of pixels of similar state in an image unit); the number of ascenders; the number of descenders; the average pixel density; the length of a top line contour, including peaks and troughs; the length of a base contour, including peaks and troughs; the location of image units with respect to neighboring image units; vertical position; horizontal inter-image unit spacing; and combinations of such classifiers. Thus, for example, if a selection criteria is chosen to produce a document summary from titles in the document, only title information in the document need be retrieved by the image analysis processes described above. On the other hand, if a more comprehensive evaluation of the document contents is desired, then more comprehensive identification techniques would need to be employed.

In addition, morphological image recognition techniques such as those disclosed in concurrently filed U.S. patent application Ser. No. 07/775,174, to Bloomberg et al., and entitled "Methods and Apparatus for Automatic Modification of Selected Semantically Significant Portions of a Document Without Document Image Decoding", can be used to recognize specialized fonts and typefaces within the document image.

More particularly, the above reference provides a method for automatically emphasizing selected information within the data or text of a document image. Referring to FIG. 9, the first phase of the image processing technique of the method involves the segmentation of the image into undecoded information containing image units (step 920) using techniques described above. Then the locations of and spatial relationships between the image units on a page is determined (step 925), which was previously described.

The discrimination step 930, which was previously described, is next performed to identify the image units which have insufficient information content to be useful in evaluating the subject matter content of the document being processed. Such image units include stop or function words, i.e., prepositions, articles and other words that play a largely grammatical role, as opposed to nouns and verbs that convey topic information.

Next, in step 940, selected image units, e.g., the image units not discriminated in step 930, are evaluated, without decoding the image units being classified or reference to decoded image data, based on an evaluation of predetermined morphological (structural) image characteristics of the image units. The evaluation entails a determination (step 941) of the morphological image characteristics and a comparison (step 942) of the determined morphological image characteristics for each image unit. The determined morphological image characteristic(s), e.g., the derived image unit shape representations, of each selected image unit are compared, either with the determined morphological image characteristic(s)/derived image unit shape representations of the other selected image units (step 942A), or with predetermined/user-selected morphological image characteristics to locate specific types of image units (step 942B). The determined morphological image characteristics of the selected image units are advantageously compared with each other for the purpose of identifying equivalence classes of image units such that each equivalence class contains most or all of the instances of a given image unit in the document, and the relative frequencies with which image units occur in a document can be determined.

It will be appreciated that the specification of the morphological image characteristics for titles, headings, captions, linguistic criteria or other significance indicating features of a document image can be predetermined and selected by the user to determine the selection criteria defining a "significant" image unit. Comparing the image characteristics of the selected image units of the document image for matches with the image characteristics associated with the selection criteria permits the significant image units to be readily identified without any document decoding.

Any of a number of different methods of comparison can be used. One technique that can be used, for example, is by correlating the raster images of the extracted image units using decision networks, such technique being described for characters in a Research Report entitled "Unsupervised Construction of Decision Networks for Pattern Classification" by Casey et al., IBM Research Report, 1984, incorporated herein in its entirety.

Another techniques that can be used to identify equivalence classes of word units are the word shape comparison

techniques disclosed in U.S. patent application Ser. Nos. 07/796,119 and 07/795,169, filed concurrently herewith by Huttenlocher and Hopcroft, and by Huttenlocher, Hopcroft and Wayner, respectively, and entitled, respectively, "Optical Word Recognition By Examination of Word Shape," and "Method for Comparing Word Shapes." This method provides an adequate comparison for purposes of determining phrase frequency is to compare only the length and height of the derived image unit shape representations. Such a comparison is particularly fast, resulting in a highly efficient phrase frequency analysis which has proven to be sufficiently robust to reliably extract significant phrases in many text document applications.

In instances in which multiple page documents are processed, each page is processed and the data held in the memory 15 (see FIG. 1), as described above. The entirety of the data can then be processed.

The second phase of the document analysis according to this method involves further processing (step 950) of the scanned document image to emphasize the identified image units. The emphasis can be provided in numerous ways. One exemplary way is to augment the document image so that the identified significant image units are underscored, highlighted with color, or presented as margin notations.

Another exemplary way is to modify the shape and/or other appearance attributes of the significant image units themselves in a manner which emphasizes them relative to the other image units in the document image. The appearance modification can be accomplished using any conventional image modification techniques, or, advantageously, the following morphological bitmap modification techniques.

In accordance with this method, one or more selected morphological operations are performed uniformly on the entire bitmap for a selected image unit to modify at least one shape characteristic thereof. It will be appreciated that the selection of bitmap operations may be performed automatically or interactively.

Examples of ways in which the appearance changes described above can be accomplished are as follows. The type style text can be "boldened" by either "dilation" or using a connectivity-preserving (CP) thickening operation. It can be "lightened" by either "erosion" or a CP thinning operation. (As will be appreciated by those skilled in the art, dilation and erosion are morphological operations which map a source image onto an equally sized destination image according to a rule defined by a pixel pattern called a structuring element (SE). A SE is defined by a center location and a number of pixel locations, each having a defined value (ON or OFF). The pixels defining the SE do not have to be adjacent each other. The center location need not be at the geometrical center of the pattern; indeed it need not even be inside the pattern. In a dilation, a given pixel in the source image being ON causes the SE to be written into the destination image with the SE center at the corresponding location in the destination image. The SEs used for dilation typically have no OFF pixels. In an erosion, a given pixel in the destination image is turned ON if and only if the result of superimposing the SE center on the corresponding pixel location in the source image results in a match between all ON and OFF pixels in the SE and the underlying pixels in the source image.)

Such dilation/thickening and erosion/thinning operations can be either isotropic (the same horizontally for vertically) or anisotropic (e.g., different in horizontal and vertical directions).

Although optical character recognition (OCR) techniques are required, for example, in order to convert the typestyle

of a selected word unit to italic, a similar type of emphasis can be achieved through the morphological operation of horizontal shearing to achieve the slant typestyle. Slant is a variant of roman type style that is created from roman using a horizontal shear of about 12 degrees (this is the approximate slant angle of italic style characters). The sheared images can slant forwards, backwards, or even upwards, if desired. Text can also be bit inverted (black for white and vice versa) for emphasis, or words can be emphasized or de-emphasized by scaling up or down, respectively. In the case of scaling, it may also be desirable to change the thickness of the lines in the image unit in addition to simple scaling.

Thus, using such morphological bitmap alteration processes, hand marks such as underlining, side lining, circling, highlighting, and so forth, can be extracted from the image, and removed from the original bitmap by XOR operations. Removal of color highlight marks requires capture of a gray scale (or color) scanned image. Once captured, removal is relatively easy using the appropriate thresholding. The resulting image is similar in quality to that of un-highlighted marks. Words that are high-lighted can be identified from the highlight mask and word boxes, using known seed-growing methods. The appearance of these words can be altered at will.

A salient feature provided by the method of the invention is that the initial processing and identification of significant image units is accomplished without an accompanying requirement that the content of the image units be decoded, or that the information content of the document image otherwise be understood. More particularly, to this stage in the process, the actual content of the word units is not required to be specifically determined. Thus, for example, in such applications as copier machines or electronic printers that can print or reproduce images directly from one document to another without regard to ASCII or other encoding/decoding requirements, image units can be identified and processed using one or more morphological image characteristics or properties of the image units. The image units of unknown content can then be further optically or electronically processed. One of the advantages that results from the ability to perform such image unit processing without having to decode the image unit contents at this stage of the process is that the overall speed of image handling and manipulation can be significantly increased.

The second phase of the document analysis of the invention involves processing (step 50) the identified significant image units to produce an auxiliary or supplemental document image reflective of the contents of the source document image. It will be appreciated that the format in which the identified significant image units are presented can be varied as desired. Thus, the identified significant image units could be presented in reading order to form one or more phrases, or presented in a listing in order of relative frequency of occurrence. Likewise, the supplemental document image need not be limited to just the identified significant image units. If desired, the identified significant image units can be presented in the form of phrases including adjacent image units presented in reading order sequence, as determined from the document location information derived during the document segmentation and structure determination steps 20 and 25 described above. Alternatively, a phrase frequency analysis as described above can be conducted to limit the presented phrases to only the most frequently occurring phrases.

The present invention is similarly not limited with respect to the form of the supplemental document image. One

application for which the information retrieval technique of the invention is particularly suited is for use in reading machines for the blind. One embodiment supports the designation by a user of key words, for example, on a key word list, to designate likely points of interest in a document. Using the user designated key words, occurrences of the word can be found in the document of interest, and regions of text forward and behind the key word can be retrieved and processed using the techniques described above. Or, as mentioned above, significant key words can be automatically selected according to prescribed criteria, such as frequency of occurrence, or other similar criteria, using the morphological image recognition techniques described above; and a document automatically summarized using the determined words.

Another embodiment supports an automatic location of significant segments of a document according to other predefined criteria, for example, document segments that are likely to have high informational value such as titles, regions containing special font information such as italics and boldface, or phrases that receive linguistic emphasis. The location of significant words or segments of a document may be accomplished using the morphological image recognition techniques described above. The words thus identified as significant words or word units can then be decoded using optical character recognition techniques, for example, for communication to the blind user in a Braille or other form which the blind user can comprehend. For example, the words which have been identified or selected by the techniques described above can either be printed in Braille form using an appropriate Braille format printer, such as a printer using plastic-based ink; or communicated orally to the user using a speech synthesizer output device.

Once a condensed document is communicated, the user may wish to return to the original source to have printed or hear a full text rendition. This may be achieved in a number of ways. One method is for the associated synthesizer or Braille printer to provide source information, for example, "on top of page 2 is an article entitled . . ." The user would then return to point of interest.

Two classes of apparatus extend this capability through providing the possibility of user interaction while the condensed document is being communicated. One type of apparatus is a simple index marker. This can be, for instance, a hand held device with a button that the user depresses whenever he or she hears a title of interest, or, for instance, an N-way motion detector in a mouse 19 (FIG. 2) for registering a greater variety of commands. The reading machine records such marks of interest and returns to the original article after a complete summarization is communicated.

Another type of apparatus makes use of the technology of touch-sensitive screens. Such an apparatus operates by requiring the user to lay down a Braille summarization sheet 41 on a horizontal display. The user then touches the region of interest on the screen 42 in order to trigger either a full printout or synthesized reading. The user would then indicate to the monitor when a new page was to be processed.

It will be appreciated that the method of the invention as applied to a reading machine for the blind reduces the amount of material presented to the user for evaluation, and thus is capable of circumventing many problems inherent in the use of current reading technology for the blind and others, such as the problems associated with efficient browsing of a document corpus, using synthesized speech, and the problems created by the bulk and expense of producing Braille paper translations, and the time and effort required by the user to read such copies.

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The present invention is useful for forming abbreviated document images for browsing (image gists). A reduced representation of a document is created using a bitmap image of important terms in the document. This enables a user to quickly browse through a scanned document library, either electronically, or manually if summary cards are printed out on a medium such as paper. The invention can also be useful for document categorization (lexical gists). In this instance, key terms can be automatically associated with a document. The user may then browse through the key

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terms, or the terms may be further processed, such as by decoding using optical character recognition.

Although the invention has been described and illustrated with a certain degree of particularity, it is understood that the present disclosure has been made only by way of example, and that numerous changes in the combination and arrangement of parts can be resorted to by those skilled in the art without departing from the spirit and scope of the invention, as hereinafter claimed.

APPENDIX

Jul 26 19:28 1991 args.h

```

1  /* Support for command line argument scanning.
2  *
3  * When a program is run from the shell, its name is followed by a number of
4  * required command line ARGUMENTS and then some optional command line OPTIONS.
5  * Each argument consists of a list of required PARAMETERS, each of which can
6  * be either an int, string, or float. Options are like arguments with the
7  * exception that their required parameters are preceded by a keyword denoting
8  * which option is being invoked.
9  *
10 * Required arguments are defined using the DefArg function. The format string
11 * consists of a list of data format specifiers (%d, %f, and %s for integer, float, and
12 * string, respectively) that specify the types of the parameters to the argument.
13 * The documentation string should contain a one line description of the argument.
14 * It will be printed if the argument list cannot be scanned.
15 * The remaining arguments to DefArg are pointers to locations where the values of the
16 * command line arguments will be stored.
17 *
18 * Optional arguments are defined with the DefOption function. The format string
19 * is similar to the DefArg format string, but has a keyword before the format
20 * specifiers. The exists parameter is a pointer to BOOLEAN that is set to true
21 * iff an occurrence of this option was successfully parsed from the command line.
22 * The remaining arguments are pointers to the locations where the values of the
23 * command line arguments will be stored.
24 *
25 * Short example:
26 * The following program expects one required command line argument that is a string
27 * and will be stored in s. In addition, it will accept three different optional
28 * keyword arguments. They are the keyword -int followed by an integer, with result
29 * stored in i; -float followed by a float stored in f; and -pair followed by a float
30 * and then an int, stored in f and i, respectively.
31 *
32 * Suppose the program is called foo. Here are some legal invocations:
33 * % foo hello
34 * % foo hello -int 1
35 * % foo hello -int 5 -float 10
36 * % foo hello -pair 1 2
37 *
38 * Here are some error invocations and responses
39 * % foo
40 * Usage:
41 * scanArgs
42 * filename
43 * [-int <int>]
44 * [-float <float>]
45 * [-pair <float> <int>]
46 * % foo hello -int
47 * Option -int expects 1 parameters:
48 * -int <int>
49 *
50 *
51 *void main (int argc, char **argv)

```

Section A

APPENDIX / Page 2

```

52  *{
53  * int i;
54  * float f;
55  * char *s;
56  * BOOLEAN haveAString,haveAnInt,haveAFloat,haveAPair;
57  *
58  * DefArg("%s","filename",&s);
59  * DefOption("-int %d","-int <int>",&haveAnInt,&i);
60  * DefOption("-float %f","-float <float>",&haveAFloat,&f);
61  * DefOption("-pair %f %d","-pair <float> <int>",&haveAPair,&f,&i);
62  *
63  * ScanArgs(argc,argv);
64  *
65  * printf("%s\n",s);
66  * if (haveAPair)
67  *   printf("%f %d\n",f,i);
68  * if (haveAnInt)
69  *   printf("%d\n",i);
70  * if (haveAFloat)
71  *   printf("%f\n",f);
72  * if (haveAString)
73  *   printf("%s\n",s);
74  *}
75  *
76  */
77
78  /* Possible additions:
79  * 1) Passing NULL pointers as exists variables.
80  * 2) Predicate calculus for error checking.
81  * 3) Only need one DefArg call.
82  * 4) Combine with error.c to save program name info.
83  */
84  void DefArg(char *format,char *documentation,...);
85  void DefOption(char *format,char *documentation,BOOLEAN *exists,...);
86  void ScanArgs(int argc,char **argv);
87
88

```

Section A

APPENDIX / Page 3

Jan 11 17:00 1991 baselines.h

```
1 List BaseLines(Picture pict,double angle,char *plotFile);
2 #ifdef foo
3 int *count,
4     int **returnCoordx, int **returnCoordy);
5 #endif
6 void DrawBaseLines(Picture pict, List pointList, double angle);
```

Section A

APPENDIX / Page 4

Aug 23 13:03 1991 blobify.h

```
1 Picture Blobify(Picture old,int half_mask_size,double threshold);  
2 Picture NewBlobify(Picture old,int halfMaskWidth,double threshold,double angle);
```

Section A

APPENDIX / Page 5

Aug 1 02:59 1991 boolean.h

```
1  typedef int BOOLEAN;  
2  #define FALSE 0  
3  #define TRUE (IFALSE)
```

Section A

APPENDIX / Page 6

Jan 11 17:00 1991 boxes.h

```
1 List FindBorders(Picture pict,double theta);  
2 void DrawBox(Picture pict,Box box);  
3 void DrawColorBox(Picture pict,Box box,int color);
```

Section A

APPENDIX / Page 7

Jul 26 13:42 1991 descriptors.h

```
1  typedef unsigned char *Descriptor,DescriptorElement;
2
3  void PrintField(char *s,int w);
4  void PrintDescriptor(Descriptor d,int *starCount,int *correctCount);
5  void PrintWords(char **words,int numberOfWords);
6  Descriptor ComputeDescriptor(int modelIndex,Dictionary models,
7                               Dictionary thisFont,int numberOfWords,
8                               DiffDescriptor dd);
9
10 #define MAX_FONTS (20)
11 #define MAX_WORDS (100)
12
13
```

Section A

APPENDIX / Page 8

Jan 16 12:55 1991 dict.h

```

1      /* Dictionary file have the following format:
2      * int magic number = 1234567
3      * int numberOfEntries
4      * int infoStringLength (includes the \0 at the end)
5      * char infoString[infoStringLength]
6      * OutlinePairBody[numberOfEntries]
7      */
8
9      typedef struct {
10         Box box;
11         float blackoutHeight;
12         int numberOfLegs;
13         int offset;
14         int width;
15         float *x;
16         float *top;
17         float *bottom;
18     } *OutlinePair, OutlinePairBody;
19
20     typedef struct {
21         Box box;
22         int numberOfLegs;
23         int *x;
24         int *top;
25         int *bottom;
26     } *RawOutlinePair, RawOutlinePairBody;
27
28     typedef struct {
29         int numberOfEntries;
30         char *infoString;
31         RawOutlinePair *rawOutlines;
32         OutlinePair *outlines;
33     } *Dictionary, DictionaryBody;
34
35     void WriteDictionary(Dictionary dict, char *filename);
36     Dictionary ReadDictionary(char *filename);
37     Dictionary NewDict(int numberOfEntries);
38     char *ArgListToString(int argc, char **argv);

```


Section A

APPENDIX / Page 9

Jul 30 23:04 1991 diff.h

```
1     typedef enum {L2,CONSTRAINED,WARP} DiffType;
2
3     typedef struct {
4         DiffType diffType;
5         BOOLEAN lengthNormalize;
6         BOOLEAN separate;
7         float centerWeight;
8         int bandWidth;
9         float topToBottom;
10        float hillToValley;
11        FILE *pathFP;
12    } *DiffDescriptor,DiffDescriptorBody;
13
14    Picture CompareDictionaries(Dictionary dict1, Dictionary dict2,DiffDescriptor dd);
15    void WritePictureAsAscii(Picture pict, char *filename,
16                           char *info1, char *info2);
17    float DiffPair(OutlinePair one, OutlinePair two,DiffDescriptor dd);
18    #ifdef foo
19    float DiffPairAndPath(OutlinePair one, OutlinePair two,DiffDescriptor dd);
20    #endif
21
22
23
```

Section A

APPENDIX / Page 10

Jan 15 18:56 1991 diff2.h

```
1  #ifdef OWNER
2  #define EXTERN
3  #else
4  #define EXTERN extern
5  #endif OWNER
6
7  EXTERN int FileCountX;
8  EXTERN int FileCountY;
9
10 float DiffPair(OutlinePair one, OutlinePair two, char *matchtype,
11               char *pathFile);
12
```

Section A

APPENDIX / Page 11

Jul 26 19:29 1991 error.h

```
1  /* Possible additions:
2   * 1) Variable numbers of parameters to DoError().
3   * 2) Error recovery language.
4   */
5  void DoError(char *string1, char *string2);
```

Section A

APPENDIX / Page 12

Aug 15 06:37 1991 fontNorm.h

```
1 void StoreRawOutlinePair(Dictionary dict, int dictEntry,  
2     Box box, int *bothX, int *topY, int *baseY,  
3     int numberOfLegs);  
4  
5 #define HIT_THE_BOX (10000)  
6
```

Section A

APPENDIX / Page 13

Jan 11 17:00 1991 lines.h

```
1  typedef BOOLEAN pistFunc(Picture pict, int x, int y, BOOLEAN test,  
2                          UCHAR color);  
3  
4  pistFunc DrawPiston, CountPiston, DistancePiston, BaseLinePiston;  
5  
6  void LineEngine(Picture pict, int x1, int y1, int x2, int y2, UCHAR color,  
7                  pistFunc PerPixel);  
8  void DrawLine(Picture pict, int x1, int y1, int x2, int y2, UCHAR color);  
9  float CountLine(Picture pict, int x1, int y1, int x2, int y2);  
10 int DistanceLine(Picture pict, int x1, int y1, int x2, int y2);
```

Section A

APPENDIX / Page 14

Jan 11 17:00 1991 lists.h

```
1     typedef struct {
2         void *car;
3         void *cdr;
4     } cellBody,*cell;
5
6     typedef cell List;
7     typedef void *mapFun(void *);
8     typedef void collectFun(void *);
9
10    List cdr(List);
11    void *car(List);
12    void *poplIntern(List *);
13    BOOLEAN endp(List);
14    List cons(void *,List);
15    void map(List,mapFun);
16    List collect(List,collectFun);
17    int ListLength(List l);
18
19    #define push(a,l) ((l) = cons((a),(l)))
20    #define pop(l) (poplIntern(&(l)))
21    #define nil ((List)NULL)
```

Section A

APPENDIX / Page 15

Jan 15 18:39 1991 match.h

```

1  #ifdef OWNER
2  #define EXTERN
3  #else
4  #define EXTERN extern
5  #endif OWNER
6
7  EXTERN int debug;
8
9  typedef struct {
10     float cost;
11     int xptr;
12     int yptr;
13 } elt;
14
15 #define MAXSEQLENGTH 800
16
17 float DPDiffPair(OutlinePair one, OutlinePair two);
18 float matchvecs(float *Vec1, int lenVec1, float *Vec2, int lenVec2);
19 float sq_distance(float x1, float x2);
20 float best_score(elt *array[][MAXSEQLENGTH], int lenVec1, int lenVec2);
21 void print_best_path(elt *array[][MAXSEQLENGTH], int lenVec1, int lenVec2,
22                     char *pathFile);
23 void print_array_costs(elt *array[][MAXSEQLENGTH], int lenVec1, int lenVec2);
24 void print_array_dirs(elt *array[][MAXSEQLENGTH], int lenVec1, int lenVec2);
25
26 /*
27 #ifndef debug
28 #define debug FALSE
29 #endif
30 */
31 #ifndef horweight
32 #define horweight 1.5
33 #endif
34
35 #ifndef verweight
36 #define verweight 1.5
37 #endif
38
39 #ifndef diagweight
40 #define diagweight 1.0
41 #endif

```

Section A

APPENDIX / Page 16

Jan 15 18:47 1991 matchparallel.h

```
1    float pl_DPDiffPair(OutlinePair one, OutlinePair two, char *pathFile);
2    float pl_matchvecs(float *Vec1t, float *Vec1b, int lenVec1, float *Vec2t, float *Vec2b, int
lenVec2, char *pathFile);
3
4    float faster_pl_DPDiffPair(OutlinePair one, OutlinePair two, char *pathFile);
5    float faster_pl_matchvecs(float *Vec1t, float *Vec1b, int lenVec1, float *Vec2t, float *Vec2b,
int lenVec2, char *pathFile);
6
7    float simple_pl_DPDiffPair(OutlinePair one, OutlinePair two);
8    float simple_pl_matchvecs(float *Vec1t, float *Vec1b, int lenVec1, float *Vec2t, float
*Vec2b, int lenVec2);
```


Jul 9 16:01 1991 misc.h

```

1  /*
2  *
3  * misc.h - miscellaneous types and declarations
4  *
5  */
6
7  /* Some library routines that never seem to get declared */
8
9  /* Memory allocation functions */
10 extern void *malloc(unsigned size);
11 extern void *calloc(unsigned nelem, unsigned elsize);
12 extern void *realloc(void *p, unsigned size);
13 extern void free(void *p);
14
15 /* I don't feel like including setjmp.h */
16 /*
17 extern int _setjmp(jmp_buf env);
18 extern volatile void _longjmp(jmp_buf env, int val);
19 */
20
21 /* String-to-X functions */
22 extern int atoi(char *s);
23 extern double atof(char *s);
24
25 /* String functions */
26 extern int strcmp(char *s1, char *s2);
27 extern int strncmp(char *s1, char *s2, int n);
28 extern char *strcpy(char *d, char *s);
29 extern char *strncpy(char *d, char *s, int n);
30 int strlen(char *s);
31 extern char *strdup(char *);
32 extern char *strchr(char *s, char c);
33
34 /* stdio functions */
35 extern int fclose(FILE *stream);
36 extern int fread(char *ptr, int size, int nitems, FILE *stream);
37 extern int fwrite(char *ptr, int size, int nitems, FILE *stream);
38 /* these are necessary to avoid implicit declarations */
39 extern int _flsbuf();
40 extern int _filbuf();
41
42 /* Formatted I/O functions */
43 extern int printf(char *format, ...);
44 extern int scanf(char *format, ...);
45 extern int fprintf(FILE *stream, char *format, ...);
46 extern int fscanf(FILE *stream, char *format, ...);
47
48 /* and misc stuff */
49 extern volatile void exit(int val);
50
51 extern void perror(char *s);
52

```

Section A

APPENDIX / Page 18

Aug 1 02:59 1991 mylib.h

```
1    #include "error.h"
2    #include "boolean.h"
3    #include "lists.h"
4    #include "args.h"
5    #include "pict.h"
6    #include "read.h"
```

Section A

APPENDIX / Page 19

Aug 15 06:36 1991 newContour.h

```
1 void BoxToShell(Picture pict,Box box,List baseLinePoints,  
2 Dictionary dict,int dictEntry,NormalizationDescriptor *nd);  
3 void BarBoxList(Picture pict,List boxList,List baseLinePoints,  
4 char *filename, char *InfoString, NormalizationDescriptor *nd);  
5  
6  
7
```

Section A

APPENDIX / Page 20

Jul 31 17:11 1991 newMatch.h

```
1  extern float hillToValley;
2  extern float L2Compare(OutlinePair o1,OutlinePair o2,float topToBottom);
3  extern float NewMatch(float *a1,float *a2,int aLength,float *b1,float *b2,int bLength,
4      float centerWeight,BOOLEAN lengthNormalize,int normalBandWidth,
5      float topToBottom);
6  extern float SepMatch(float *a1,int aLength,float *b1,int bLength,
7      float centerWeight,BOOLEAN lengthNormalize,int normalBandWidth);
8  extern float NewMatchAndPath(float *a1,float *a2,int aLength,float *b1,float *b2,
9      int bLength,float centerWeight,BOOLEAN lengthNormalize,int normalBandWidth,
10     float topToBottom,FILE *fp);
11 extern float SlopeCMatch(float *a1,float *a2,int aLength,float *b1,float *b2,int bLength,
12     float centerWeight,BOOLEAN lengthNormalize,float topToBottom);
13 extern float SepSlopeCMatch(float *a1,int aLength,float *b1,int bLength,
14     float centerWeight,BOOLEAN lengthNormalize);
15 extern float SlopeCMatchAndPath(float *a1,float *a2,int aLength,float *b1,float *b2,
16     int bLength,float centerWeight,BOOLEAN lengthNormalize,float topToBottom,
17     FILE *pathFP);
```

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79

80

Section A

APPENDIX / Page 21

Jan 11 17:00 1991 numbers.h

```
1 void DrawNumber(Picture pict, int x, int y, int color, float scale, int n);  
2
```

Section A

APPENDIX / Page 22

Jan 14 16:52 1991 orient.h

```
1  BOOLEAN Coarse(Picture pict, int coarseSamples, int coarseDirections,  
2      float *orientation, char *plotFile);  
3  
4  float Fine(Picture pict, int fineSamples, int fineDirections,  
5      int coarseDirections, float coarseAngle, char *plotFile);  
6  
7  float NewFine(Picture pict, int fineSamples, int fineDirections,  
8      float angleStart, float angleEnd, char *plotFile);
```

Section A

APPENDIX / Page 23

Aug 23 19:19 1991 pict.h

```

1  typedef unsigned char UCHAR;
2
3  #define ROUND8(x) ((x%8)?(x+8-x%8):x)
4  #define ROUND16(x) ((x%16)?(x+16-x%16):x)
5  #define ROUND2(x) ((x%2)?(x+1):x)
6
7  typedef int Color;
8  #define COLOR_RED 0
9  #define COLOR_GREEN 1
10 #define COLOR_BLUE 2
11
12 typedef struct cmapstruct {
13     int numberOfEntries;
14     UCHAR *red;
15     UCHAR *green;
16     UCHAR *blue;
17 } ColorMapBody, *ColorMap;
18
19 typedef struct pstruct {
20     int width;
21     int height;
22     int depth;
23     int uchar_width;
24     ColorMap cmap;
25     UCHAR *data;
26 } PictureBody, *Picture;
27
28 void doerror(char *string1, char *string2);
29
30
31 ColorMap NewColorMap(int size);
32 void FreeColorMap(ColorMap cmap);
33 UCHAR ReadColorValue(ColorMap cmap, Color primary, int index);
34 UCHAR WriteColorValue(ColorMap cmap, int index, UCHAR red, UCHAR green,
35     UCHAR blue);
36 Picture new_pict(int width, int height, int depth);
37 void free_pict(Picture pict);
38 Picture load_pict(char *filename);
39 Picture load_header(FILE *fp);
40 void write_pict(char *filename, Picture pict);
41 void write_header(FILE *fp, Picture pict);
42 /*int BytesPerScanline(Picture pict); */
43 #define BytesPerScanline(pict) (pict->uchar_width)
44
45 UCHAR ReadPixel(Picture pict, int x, int y);
46 void WritePixel(Picture pict, int x, int y, int color);
47 void WriteClippedPixel(Picture pict, int x, int y, int color);
48 void CopyPicture(Picture dest, Picture src);
49

```

Section A

APPENDIX / Page 24

Jul 26 13:09 1991 read.h

```
1  int ReadInt(FILE *fp);
2  int ReadFloat(FILE *fp);
3  char *ReadString(FILE *fp);
4
```


Section A

APPENDIX / Page 25

Aug 15 00:19 1991 types.h

```
1  typedef struct {
2      BOOLEAN noAscenderNormalize;
3      BOOLEAN noXHeightNormalize;
4  } NormalizationDescriptor;
5
6  typedef struct {
7      int x;
8      int y;
9      int width;
10     int height;
11     int pageX;
12     int pageY;
13     double angle;
14 } BoxBody, *Box;
15
16 typedef struct {
17     int x;
18     int y;
19 } PointBody, *Point;
20
21 Box MakeBox(int x,int y,int width,int height,double angle);
22 Point MakePoint(int x,int y);
```

Section B

APPENDIX / Page 26

Jul 26 13:25 1991 Makefile

```

1  CCFLAGS = -g -c -I/net/piglet/piglet-1c/hopcroft/new/include
2
3  INCLUDE = /net/piglet/piglet-1c/hopcroft/new/include/
4
5  ARGS = $(INCLUDE)args.h
6  BOOLEAN = $(INCLUDE)boolean.h
7  ERROR = $(INCLUDE)error.h
8  LISTS = $(INCLUDE)lists.h
9  MISC = $(INCLUDE)misc.h
10 PICT = $(INCLUDE)pict.h
11 READ = $(INCLUDE)read.h
12
13 OFUNS = args.o error.o pict.o lists.o read.o
14
15 mylib.a: $(OFUNS)
16     ld -r $(OFUNS) -o mylib.a
17
18 args.o:    args.c $(BOOLEAN) $(ERROR) $(MISC) $(ARGS)
19     gcc $(CCFLAGS) args.c
20
21 error.o:   error.c $(ERROR)
22     gcc $(CCFLAGS) error.c
23
24 pict.o:    pict.c $(BOOLEAN) $(ERROR) $(PICT)
25     gcc $(CCFLAGS) pict.c
26
27 lists.o:   lists.c $(BOOLEAN) $(LISTS)
28     gcc $(CCFLAGS) lists.c
29
30 read.o:    read.c $(MISC) $(READ)
31     gcc $(CCFLAGS) read.c
32
33

```

Jul 26 13:23 1991 args.c

```

1  #include <stdio.h>
2  #include <stdarg.h>
3  #include "error.h"
4  #include "boolean.h"
5  #include "misc.h"
6  #include "args.h"
7
8  #define MAX_NAME_LENGTH (50)
9  #define MAX_PARAMETERS (6)
10 #define MAX_OPTIONS (20)
11 #define MAX_ARGS (20)
12
13 typedef enum {INTEGER,FLOAT,STRING} ParamType;
14
15 typedef struct {
16     char *documentation;
17     int numberOfParameters;
18     ParamType types[MAX_PARAMETERS];
19     void *values[MAX_PARAMETERS];
20 } *Arg,ArgBody;
21
22 typedef struct {
23     char optionName[MAX_NAME_LENGTH+1];
24     char *documentation;
25     BOOLEAN *exists;
26     int numberOfParameters;
27     ParamType types[MAX_PARAMETERS];
28     void *values[MAX_PARAMETERS];
29 } *Option,OptionBody;
30
31 static BOOLEAN optionsRequired = TRUE;
32 static int numberOfArguments = 0;
33 static ArgBody args[MAX_ARGS];
34 static int numberOfOptions = 0;
35 static OptionBody options[MAX_OPTIONS];
36
37 void DefArg(char *format,char *documentation,...)
38 {
39     va_list ap;
40     char *p;
41     int i;
42     int parameterCounter;
43
44     if (numberOfArguments == MAX_ARGS)
45         DoError("Def Arg: too many command line options now:\n%s\n",format);
46
47     args[numberOfArguments].documentation = documentation;
48
49     /* now parse the format string */
50     /* get option parameters */
51     va_start(ap,documentation);
52     for (p=format,parameterCounter=0;*p;p++){

```

Section B

APPENDIX / Page 28

```

53     if (*p == '%') {
54         if (parameterCounter == MAX_PARAMETERS)
55             DoError("Def Arg: too many parameters in \"%s\".\n", format);
56         p++;
57         switch (*p) {
58             case 'd':
59                 args[numberOfArguments].types[parameterCounter] = INTEGER;
60                 args[numberOfArguments].values[parameterCounter] = va_arg(ap, void *);
61                 parameterCounter++;
62                 break;
63             case 'f':
64                 args[numberOfArguments].types[parameterCounter] = FLOAT;
65                 args[numberOfArguments].values[parameterCounter] = va_arg(ap, void *);
66                 parameterCounter++;
67                 break;
68             case 's':
69                 args[numberOfArguments].types[parameterCounter] = STRING;
70                 args[numberOfArguments].values[parameterCounter] = va_arg(ap, void *);
71                 parameterCounter++;
72                 break;
73             default:
74                 DoError("DefArg: bad option in \"%s\".\n", format);
75         }
76     }
77 }
78 args[numberOfArguments].numberOfParameters = parameterCounter;
79 ++numberOfArguments;
80 va_end(ap);
81 }
82
83 void DefOption(char *format, char *documentation, BOOLEAN *exists, ...)
84 {
85     va_list ap;
86     char *optionName;
87     char *p;
88     int i;
89     int parameterCounter;
90
91     if (numberOfOptions == MAX_OPTIONS)
92         DoError("DefOption: too many command line options now: \"%s\".\n", format);
93
94     /* record exists so that *exists will be TRUE if this option is scanned */
95     options[numberOfOptions].exists = exists;
96
97     options[numberOfOptions].documentation = documentation;
98
99     /* now parse the format string */
100    p = format;
101    /* skip leading spaces */
102    while (*p == ' ' && *p != '\0')
103        p++;
104
105    /* get the option name */
106    optionName = options[numberOfOptions].optionName;
107    i = 0;

```

```

108 while (*p != '\0' && *p != ' ' && *p != '\t') {
109     if (i < MAX_NAME_LENGTH)
110         optionName[i++] = *p;
111     else
112         DoError("DefOptions: option name too long in \"%s\".\n",format);
113     p++;
114 }
115 optionName[i] = '\0';
116
117 /* get option parameters */
118 va_start(ap,exists);
119 for (parameterCounter=0;*p;p++){
120     if (*p == '%') {
121         if (parameterCounter == MAX_PARAMETERS)
122             DoError("DefOptions: too many parameters in \"%s\".\n",format);
123         p++;
124         switch (*p) {
125             case 'd':
126                 options[numberOfOptions].types[parameterCounter] = INTEGER;
127                 options[numberOfOptions].values[parameterCounter] = va_arg(ap, void *);
128                 parameterCounter++;
129                 break;
130             case 'f':
131                 options[numberOfOptions].types[parameterCounter] = FLOAT;
132                 options[numberOfOptions].values[parameterCounter] = va_arg(ap, void *);
133                 parameterCounter++;
134                 break;
135             case 's':
136                 options[numberOfOptions].types[parameterCounter] = STRING;
137                 options[numberOfOptions].values[parameterCounter] = va_arg(ap, void *);
138                 parameterCounter++;
139                 break;
140             default:
141                 DoError("DefOptions: bad option in \"%s\".\n",format);
142         }
143     }
144 }
145 options[numberOfOptions].numberOfParameters = parameterCounter;
146 ++numberOfOptions;
147 va_end(ap);
148 }
149
150 void PrintHelp(char *name)
151 {
152     int i;
153     fprintf(stderr,"Usage:\n %s\n",name);
154     for (i=0;i<numberOfArguments; ++i)
155         fprintf(stderr," %s\n",args[i].documentation);
156     for (i=0;i<numberOfOptions; ++i)
157         fprintf(stderr," [%s]\n",options[i].documentation);
158     DoError("\n",NULL);
159 }
160
161 void ScanArgs(int argc,char **argv)
162 {

```

Section B

APPENDIX / Page 30

```

163     int i,j,k;
164
165     for (j=0;j<numberOfOptions; ++j)
166         *(options[j].exists) = FALSE;
167
168     if (argc == 1 && optionsRequired)
169         PrintHelp(argv[0]);
170
171     i=1;
172     for (j=0;j<numberOfArguments; ++j) {
173         if (i+args[j].numberOfParameters > argc) {
174             fprintf(stderr, "Required argument expects %d parameters:\n %s\n",
175                 args[j].numberOfParameters,
176                 args[j].documentation);
177             DoError("\n",NULL);
178         }
179         for (k=0;k<args[j].numberOfParameters; ++k)
180             switch (args[j].types[k]) {
181                 case INTEGER:
182                     *(int *) (args[j].values[k]) = atoi(argv[i + +]);
183                     break;
184                 case FLOAT:
185                     *(float *) (args[j].values[k]) = atof(argv[i + +]);
186                     break;
187                 case STRING:
188                     *(char **) (args[j].values[k]) = argv[i + +];
189                     break;
190                 default:
191                     DoError("ScanArgs: internal error - bad type.\n",NULL);
192             }
193     }
194
195     while (i<argc) {
196         for (j=0;j<numberOfOptions; ++j)
197             if (strcmp(options[j].optionName,argv[i])) {
198                 if (i+options[j].numberOfParameters >= argc) {
199                     fprintf(stderr, "Option %s expects %d parameters:\n %s\n",
200                         options[j].optionName,
201                         options[j].numberOfParameters,
202                         options[j].documentation);
203                     DoError("\n",NULL);
204                 }
205                 *(options[j].exists) = TRUE;
206                 ++i;
207                 for (k=0;k<options[j].numberOfParameters; ++k)
208                     switch (options[j].types[k]) {
209                         case INTEGER:
210                             *(int *) (options[j].values[k]) = atoi(argv[i + +]);
211                             break;
212                         case FLOAT:
213                             *(float *) (options[j].values[k]) = atof(argv[i + +]);
214                             break;
215                         case STRING:
216                             *(char **) (options[j].values[k]) = argv[i + +];
217                             break;

```

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```

218         default:
219             DoError("ScanArgs: internal error - bad type.\n",NULL);
220         }
221         break;
222     }
223     if (j == numberOfOptions) {
224         fprintf(stderr,"Bad command line argument.\n");
225         PrintHelp(argv[0]);
226     }
227 }
228 }
229 #ifdef foo
230 void main (int argc,char **argv)
231 {
232     int i;
233     float f;
234     char *s;
235     BOOLEAN haveAString,haveAnInt,haveAFloat,haveAPair;
236
237     DefArg("%s","filename",&s);
238     DefOption("-int %d","-int <int>",&haveAnInt,&i);
239     DefOption("-float %f","-float <float>",&haveAFloat,&f);
240     DefOption("-pair %f %d","-pair <float> <int>",&haveAPair,&f,&i);
241
242     ScanArgs(argc,argv);
243
244     printf("%s\n",s);
245     if (haveAPair)
246         printf("%f %d\n",f,i);
247     if (haveAnInt)
248         printf("%d\n",i);
249     if (haveAFloat)
250         printf("%f\n",f);
251     if (haveAString)
252         printf("%s\n",s);
253 }
254 #endif

```

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Jul 26 12:57 1991 error.c

```
1  #include <stdio.h>
2  #include "error.h"
3
4  void DoError(char *string1,char *string2)
5  {
6      if (string2 == NULL)
7          printf(string1);
8      else
9          printf(string1,string2);
10     exit(-1);
11 }
12
```


Jul 26 12:57 1991 lists.c

```

1  #include "stdio.h"
2  #include "boolean.h"
3  #include "lists.h"
4
5  List cdr(List l)
6  {
7      if (l == NULL)
8          return l;
9      else
10         return l->cdr;
11 }
12
13 void *car(List l)
14 {
15     if (l == NULL)
16         return l;
17     else
18         return l->car;
19 }
20
21 void *popIntern(List *l)
22 {
23     List temp;
24     if (*l == NULL)
25         return *l;
26     else {
27         temp = (*l)->car;
28         *l = (*l)->cdr;
29         return temp;
30     }
31 }
32
33 BOOLEAN endp(List l)
34 {
35     return (l == NULL);
36 }
37
38 List cons(void *theCar, List theCdr)
39 {
40     cell temp;
41     temp = (cell) calloc(1, sizeof(cellBody));
42     if (temp == NULL) {
43         printf("Cons: out of memory\n");
44         exit(-1);
45     }
46     temp->car = theCar;
47     temp->cdr = theCdr;
48     return temp;
49 }
50
51 void map(List l, mapFun f)
52 {

```

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```
53     while (l != NULL) {
54         (*f)(l->car);
55         l = l->cdr;
56     }
57 }
58
59 List collect(List l, collectFun c)
60 {
61     List temp;
62     while (l != NULL) {
63         (*c)(l->car);
64         temp = l;
65         l = l->cdr;
66         free(temp);
67     }
68 }
69
70 int ListLength(List l)
71 {
72     int count = 0;
73     while (l != NULL) {
74         ++count;
75         l = l->cdr;
76     }
77     return count;
78 }
```

Aug 23 19:20 1991 pict.c

```

1  #include <stdio.h>
2  #include <math.h>
3  #include <rasterfile.h>
4  #include "boolean.h"
5  #include "error.h"
6  #include "pict.h"
7
8  static UCHAR bitmasks[] = { 0x80,0x40,0x20,0x10,0x8,0x4,0x2,0x1 };
9
10 ColorMap NewColorMap(int size)
11 {
12     ColorMap cmap;
13     if (size > 256)
14         DoError("NewColorMap: size greater than 256.",NULL);
15     if (size < 1)
16         DoError("NewColorMap: size less than 1.",NULL);
17     if ((cmap = (ColorMap)calloc(1,sizeof(ColorMapBody))) == NULL)
18         DoError("NewColorMap: cannot allocate space.",NULL);
19     cmap->numberOfEntries = size;
20     cmap->red = (UCHAR *)calloc(size,sizeof(UCHAR));
21     cmap->green = (UCHAR *)calloc(size,sizeof(UCHAR));
22     cmap->blue = (UCHAR *)calloc(size,sizeof(UCHAR));
23     if ((cmap->red == NULL)||((cmap->green == NULL)||((cmap->blue == NULL)))
24         DoError("NewColorMap: cannot allocate space.",NULL);
25     return cmap;
26 }
27
28 void FreeColorMap(ColorMap cmap)
29 {
30     if (cmap != NULL) {
31         if (cmap->red != NULL)
32             free(cmap->red);
33         if (cmap->green != NULL)
34             free(cmap->green);
35         if (cmap->blue != NULL)
36             free(cmap->blue);
37         free(cmap);
38     }
39 }
40
41 UCHAR ReadColorValue(ColorMap cmap, Color primary, int index)
42 {
43     if (index > cmap->numberOfEntries)
44         DoError("ReadColorValue: index too big.",NULL);
45     if (primary == COLOR_RED)
46         return *(cmap->red + index);
47     if (primary == COLOR_GREEN)
48         return *(cmap->green + index);
49     if (primary == COLOR_BLUE)
50         return *(cmap->blue + index);
51     DoError("ReadColorValue: bad primary color.",NULL);
52 }

```

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```

53
54  UCHAR WriteColorValue(ColorMap cmap, int index, UCHAR red, UCHAR green,
55                          UCHAR blue)
56  {
57      if (index > cmap->numberOfEntries)
58          DoError("WriteColorValue: index too big.",NULL);
59      *(cmap->red+index)=red;
60      *(cmap->green+index)=green;
61      *(cmap->blue+index)=blue;
62  }
63
64  Picture new_pict(width,height,depth)
65  int width,height,depth;
66  {
67      Picture pict;
68      int uchar_width;
69
70      if ((pict = (Picture)calloc(1,sizeof(PictureBody))) == NULL)
71          DoError("new_pict: cannot allocate space",NULL);
72      pict->width = width;
73      pict->height = height;
74      pict->depth = depth;
75      pict->cmap = NULL;
76      if (pict->depth == 32)
77          uchar_width = pict->width*4;
78      else if (pict->depth == 8)
79          uchar_width = ROUND2(pict->width);
80      else if (pict->depth == 1)
81          uchar_width = ROUND16(pict->width) >> 3;
82      else
83          DoError("new_pict: only depths of 1 and 8 are supported\n",NULL);
84      pict->uchar_width = uchar_width;
85
86      pict->data = (UCHAR *) calloc(uchar_width * pict->height , sizeof(UCHAR));
87      if (pict->data == NULL)
88          DoError("new_pict: cannot allocate space\n",NULL);
89      return pict;
90  }
91
92  void free_pict(Picture pict)
93  {
94      {
95          if (pict->data != NULL)
96              free(pict->data);
97          FreeColorMap(pict->cmap);
98          free(pict);
99      }
100
101  Picture load_pict(fn)
102  char *fn;
103  {
104      FILE *fp;
105      Picture pict;
106      int uchar_width;
107      struct rasterfile header;

```

```

108
109     if ((pict = (Picture)calloc(1,sizeof(PictureBody))) == NULL)
110         DoError("load_pict: cannot allocate space",NULL);
111
112     if ((fp = fopen(fn, "r")) == NULL)
113         DoError("load_pict: error opening input file %s\n",fn);
114
115     /* WARNING - this fread is VERY unsafe! If assumes that the C compiler
116      * puts all fields of a structure adjacent. This is not always the case.
117      * It appears that it works with gcc on a sparcstation, but may not work
118      * on other systems. */
119     fread(&header,sizeof(struct rasterfile),1,fp);
120     if (header.ras_magic != RAS_MAGIC)
121         DoError("load_pict: only supports rasterfile format\n",NULL);
122     if ((header.ras_type != RT_STANDARD) ||
123         (header.ras_maptype != RMT_NONE) ||
124         (header.ras_maplength != 0))
125         DoError("load_pict: unsupported rasterfile format\n",NULL);
126
127     pict->width = header.ras_width;
128     pict->height = header.ras_height;
129     pict->depth = header.ras_depth;
130
131     if (pict->depth == 32)
132         uchar_width = pict->width * 4;
133     else if (pict->depth == 8)
134         uchar_width = ROUND2(pict->width);
135     else if (pict->depth == 1)
136         uchar_width = ROUND16(pict->width) >> 3;
137     else
138         DoError("load_pict: only depths of 1, 8, and 32 are supported\n",NULL);
139     pict->uchar_width = uchar_width;
140
141     pict->data = (UCHAR *) calloc(uchar_width * pict->height, sizeof(UCHAR));
142     if (pict->data == NULL)
143         DoError("load_pict: cannot allocate space\n",NULL);
144
145     fread(pict->data, sizeof(UCHAR), uchar_width*pict->height, fp);
146     fclose(fp);
147     return pict;
148 }
149
150 Picture load_header(FILE *fp)
151 {
152     Picture pict;
153     int uchar_width;
154     struct rasterfile header;
155
156     if ((pict = (Picture)calloc(1,sizeof(PictureBody))) == NULL)
157         DoError("load_header: cannot allocate space",NULL);
158
159     /* WARNING - this fread is VERY unsafe! If assumes that the C compiler
160      * puts all fields of a structure adjacent. This is not always the case.
161      * It appears that it works with gcc on a sparcstation, but may not work
162      * on other systems. */

```

```

163     if (fread(&header,sizeof(struct rasterfile),1,fp) != 1)
164         DoError("load_header: error reading header",NULL);
165     if (header.ras_magic != RAS_MAGIC)
166         DoError("load_pict: only supports rasterfile format\n",NULL);
167     if ((header.ras_type != RT_STANDARD)||
168         (header.ras_maptype != RMT_NONE) ||
169         (header.ras_maplength != 0))
170         DoError("load_pict: unsupported rasterfile format\n",NULL);
171
172     pict->width = header.ras_width;
173     pict->height = header.ras_height;
174     pict->depth = header.ras_depth;
175
176     if (pict->depth == 32)
177         uchar_width = pict->width * 4;
178     else if (pict->depth == 8)
179         uchar_width = ROUND2(pict->width);
180     else if (pict->depth == 1)
181         uchar_width = ROUND16(pict->width) >> 3;
182     else
183         DoError("load_header: only depths of 1, 8, and 32 are supported\n",NULL);
184     pict->uchar_width = uchar_width;
185     pict->data = NULL;
186
187     return pict;
188 }
189
190 void write_pict(fn, pict)
191 char *fn;
192 Picture pict;
193 {
194     FILE *fp;
195     int uchar_width;
196     struct rasterfile header;
197
198     if ((fp = fopen(fn, "w")) == NULL)
199         DoError("write_pict: error opening output file %s\n",fn);
200
201     header.ras_magic = RAS_MAGIC;
202     header.ras_width = pict->width;
203     header.ras_height = pict->height;
204     header.ras_depth = pict->depth;
205     header.ras_length = pict->uchar_width*pict->height;
206     header.ras_type = RT_STANDARD;
207     if (pict->cmap == NULL) {
208         header.ras_maptype = RMT_NONE;
209         header.ras_maplength = 0;
210     /* WARNING - this fwrite is VERY unsafe! It assumes that the C compiler
211      * puts all fields of a structure adjacent. This is not always the case.
212      * It appears that it works with gcc on a sparcstation, but may not work
213      * on other systems. */
214     if (fwrite(&header,sizeof(struct rasterfile),1,fp) != 1)
215         DoError("write_pict: error writing header",NULL);
216     }
217     else {

```

```

218     header.ras_maptype = RMT_EQUAL_RGB;
219     header.ras_maplength = pict->cmap->numberOfEntries*3;
220     /* WARNING - this fwrite is VERY unsafe! If assumes that the C compiler
221     * puts all fields of a structure adjacent. This is not always the case.
222     * It appears that it works with gcc on a sparcstation, but may not work
223     * on other systems. */
224     if (fwrite(&header,sizeof(struct rasterfile),1,fp) != 1)
225         DoError("write_pict: error writing header",NULL);
226     fwrite(pict->cmap->red,sizeof(UCHAR),pict->cmap->numberOfEntries,fp);
227     fwrite(pict->cmap->green,sizeof(UCHAR),pict->cmap->numberOfEntries,fp);
228     fwrite(pict->cmap->blue,sizeof(UCHAR),pict->cmap->numberOfEntries,fp);
229 }
230
231     uchar_width = pict->uchar_width;
232     fwrite(pict->data, sizeof(UCHAR), uchar_width*pict->height, fp);
233     fclose(fp);
234 }
235
236 void write_header(FILE *fp, Picture pict)
237 {
238     struct rasterfile header;
239
240     header.ras_magic = RAS_MAGIC;
241     header.ras_width = pict->width;
242     header.ras_height = pict->height;
243     header.ras_depth = pict->depth;
244     header.ras_length = pict->uchar_width*pict->height;
245     header.ras_type = RT_STANDARD;
246     header.ras_maptype = RMT_NONE;
247     header.ras_maplength = 0;
248     /* WARNING - this fwrite is VERY unsafe! If assumes that the C compiler
249     * puts all fields of a structure adjacent. This is not always the case.
250     * It appears that it works with gcc on a sparcstation, but may not work
251     * on other systems. */
252     fwrite(&header,sizeof(struct rasterfile),1,fp);
253 }
254
255 #define BytesPerScanline(pict) (pict->uchar_width)
256
257 UCHAR ReadPixel(pict,x,y)
258 Picture pict;
259 int x,y;
260 {
261     if (pict->depth == 8)
262         return *(pict->data+y*BytesPerScanline(pict)+x);
263     else if (pict->depth == 1)
264         return (((pict->data+y*BytesPerScanline(pict)+(x>>3))) &
265             bitmask[x%8])?1:0;
266     else
267         DoError("ReadPixel: only depths of 1 and 8 are supported\n",NULL);
268 }
269
270 void WritePixel(pict,x,y,color)
271 Picture pict;
272 int x,y;

```

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```

273     UCHAR color;
274     {
275         if (x < 0 || x >= pict->width || y < 0 || y >= pict->height) {
276             char s[256];
277             sprintf(s, "%d %d", x, y);
278             DoError("WritePixel: Out of bounds: ", s);
279         }
280         if (pict->depth == 8)
281             *(pict->data + y*pict->uchar_width + x) = color;
282         else if (pict->depth == 1)
283             if (color)
284                 *(pict->data + y*BytesPerScanline(pict) + (x > 3)) |= bitmasks[x%8];
285             else
286                 *(pict->data + y*BytesPerScanline(pict) + (x > 3)) &= ~bitmasks[x%8];
287         else
288             DoError("WritePixel: only depths of 1 and 8 are supported\n", NULL);
289     }
290
291     void WriteClippedPixel(pict, x, y, color)
292     Picture pict;
293     int x, y;
294     UCHAR color;
295     {
296         if (x < 0 || x >= pict->width || y < 0 || y >= pict->height) {
297             return;
298         }
299         if (pict->depth == 8)
300             *(pict->data + y*pict->uchar_width + x) = color;
301         else if (pict->depth == 1)
302             if (color)
303                 *(pict->data + y*BytesPerScanline(pict) + (x > 3)) |= bitmasks[x%8];
304             else
305                 *(pict->data + y*BytesPerScanline(pict) + (x > 3)) &= ~bitmasks[x%8];
306         else
307             DoError("WritePixel: only depths of 1 and 8 are supported\n", NULL);
308     }
309
310     void CopyPicture(Picture dest, Picture src)
311     {
312         int uchar_width;
313         dest->width = src->width;
314         dest->height = src->height;
315         dest->depth = src->depth;
316         dest->uchar_width = BytesPerScanline(src);
317         uchar_width = BytesPerScanline(src);
318         memcpy(dest->data, src->data, uchar_width*src->height);
319     }

```


Section B

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Jul 26 13:15 1991 read.c

```

1  #include <stdio.h>
2  #include "misc.h"
3  #include "read.h"
4
5  #define MAX_STRING_LEN (255)
6
7  int ReadInt(FILE *fp)
8  {
9      char s[MAX_STRING_LEN];
10     int x;
11
12     fgets(s,MAX_STRING_LEN,fp);
13     while (sscanf(s,"%d",&x)!= 1)
14         fprintf(stderr,"ReadInt: integer expected - reenter.\n");
15     return x;
16 }
17
18 int ReadFloat(FILE *fp)
19 {
20     char s[MAX_STRING_LEN];
21     float x;
22
23     fgets(s,MAX_STRING_LEN,fp);
24     while (sscanf(s,"%f",&x)!= 1)
25         fprintf(stderr,"ReadFloat: integer expected - reenter.\n");
26     return x;
27 }
28
29 char *ReadString(FILE *fp)
30 {
31     char s[MAX_STRING_LEN];
32     char *endPtr;
33
34     fgets(s,MAX_STRING_LEN,fp);
35     endPtr = strchr(s,'\n');
36     if (endPtr != NULL)
37         *endPtr = '\0';
38     return strdup(s);
39 }
40

```

Section C

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Aug 13 00:13 1991 Makefile

```

1  CCFLAGS = -g -c -I/net/piglet/piglet-1c/hopcroft/new/include
2
3  EXTRNS = /net/piglet/piglet-1c/hopcroft/error/error.o\
4  /net/piglet/piglet-1c/hopcroft/new/pict/pict.o\
5  /net/piglet/piglet-1c/hopcroft/lists/lists.o
6
7  ARGS_MODULE = /net/piglet/piglet-1c/hopcroft/new/ScanArgs/args.o
8
9  SOURCES = Makefile diff2.c dmain.c l2Norm2.c match.c matchparallel.c single.c
10 EXTRNSOURCES = /net/piglet/piglet-1c/hopcroft/error/error.c\
11 /net/piglet/piglet-1c/hopcroft/new/pict/pict.c\
12 /net/piglet/piglet-1c/hopcroft/lists/lists.c
13
14
15 INCLUDE = /net/piglet/piglet-1c/hopcroft/new/include/
16 ARGS = $(INCLUDE)args.h
17 BASELINES = $(INCLUDE)baselines.h
18 BLOBIFY = $(INCLUDE)blobify.h
19 BOOLEAN = $(INCLUDE)boolean.h
20 BOXES = $(INCLUDE)boxes.h
21 CONTOUR = $(INCLUDE)newContour.h
22 DESCRIPTORS = $(INCLUDE)descriptors.h
23 DICT = $(INCLUDE)dict.h
24 DIFF = $(INCLUDE)diff.h
25 DIFF2 = $(INCLUDE)diff2.h
26 ERROR = $(INCLUDE)error.h
27 LINES = $(INCLUDE)lines.h
28 LISTS = $(INCLUDE)lists.h
29 MATCH = $(INCLUDE)match.h
30 MATCHPARALLEL = $(INCLUDE)matchparallel.h
31 MISC = $(INCLUDE)misc.h
32 MYLIB = $(INCLUDE)mylib.h
33 NEWMATCH = $(INCLUDE)newMatch.h
34 ORIENT = $(INCLUDE)orient.h
35 PICT = $(INCLUDE)pict.h
36 READ = $(INCLUDE)read.h
37 TYPES = $(INCLUDE)types.h
38
39 INCSOURCES = $(BASELINES) $(BLOBIFY) $(BOOLEAN) $(BOXES) $(CONTOUR) \
40 $(DICT) $(DIFF) $(DIFF2) $(LINES) $(LISTS) $(MATCH) $(MATCHPARALLEL) \
41 $(ORIENT) $(PICT) $(TYPES)
42
43 anomalies: anomalies.o diff2.o newMatch.o ../main/dict.o
44 gcc anomalies.o diff2.o newMatch.o ../main/dict.o $(EXTRNS) -lm -o $$@
45
46 descriptors: descMain.o descriptors.o diff2.o newMatch.o newL2.o ../main/dict.o
47 gcc descMain.o descriptors.o diff2.o newMatch.o newL2.o ../main/dict.o ../lib/mylib.a
48 -lm -o $$@
49
49 drawBlobs: drawBlobs.o ../main/dict.o
50 gcc drawBlobs.o ../main/dict.o ../lib/mylib.a -lm -o $$@

```

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```

51
52 compare: diff2.o dmain.o newMatch.o ../main/dict.o
53 gcc dmain.o diff2.o newMatch.o ../main/dict.o \
54 $(EXTRNS) -lm -o $@
55
56 equiv: equiv.o descriptors.o diff2.o newMatch.o newL2.o ../main/dict.o
57 gcc equiv.o descriptors.o diff2.o newMatch.o newL2.o ../main/dict.o ../lib/mylib.a -lm
58 -o $@
59
60 extract: extract.o ../main/dict.o
61 gcc extract.o ../main/dict.o $(EXTRNS) -o $@
62
63 l2Norm: l2Norm2.o ../main/dict.o
64 gcc l2Norm2.o ../main/dict.o $(EXTRNS) -lm -o $@
65
66 recogDesc: recogDesc.o ../main/dict.o diff2.o newMatch.o newL2.o
67 gcc recogDesc.o ../main/dict.o diff2.o newMatch.o newL2.o ../lib/mylib.a -lm -o $@
68
69 resample: resample.o ../main/dict.o
70 gcc resample.o ../main/dict.o $(EXTRNS) -lm -o $@
71
72 single: single.o newMatch.o diff2.o newL2.o ../main/dict.o
73 gcc single.o newMatch.o diff2.o newL2.o ../main/dict.o ../lib/mylib.a -lm -o $@
74
75 sortMatrix: sortMatrix.o
76 gcc sortMatrix.o $(EXTRNS) -o $@
77
78 printAll: printIncludes printExtrns printCode
79
80 printCode: $(SOURCES)
81 /usr/5bin/pr -n3 $(SOURCES) | lpr -PWeeklyWorldNews
82
83 printExtrns: $(EXTRNSOURCES)
84 /usr/5bin/pr -n3 $(EXTRNSOURCES) | lpr -PWeeklyWorldNews
85
86 printIncludes: $(INCSOURCES)
87 /usr/5bin/pr -n3 $(INCSOURCES) | lpr -PWeeklyWorldNews
88
89 anomalies.o: anomalies.c $(ERROR) $(TYPES) $(PICT) $(DICT) $(DIFF) $(MISC)
90 gcc $(CCFLAGS) anomalies.c
91
92 descriptors.o: descriptors.c $(MYLIB) $(TYPES) $(DICT) $(DIFF) $(MISC) $(DESCRIPTORS)
93 gcc $(CCFLAGS) descriptors.c
94
95 descMain.o: descMain.c $(MYLIB) $(TYPES) $(DICT) $(DIFF) $(DESCRIPTORS)
96 gcc $(CCFLAGS) descMain.c
97
98 diff2.o: diff2.c $(BOOLEAN) $(TYPES) $(PICT) $(DIFF2) $(NEWMATCH)
99 gcc $(CCFLAGS) diff2.c
100
101 dmain.o: dmain.c $(BOOLEAN) $(PICT) $(DIFF)
102 gcc $(CCFLAGS) dmain.c
103
104 drawBlobs.o: drawBlobs.c $(MYLIB) $(TYPES) $(DICT)
105 gcc $(CCFLAGS) drawBlobs.c

```

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```

105
106      equiv.o:      equiv.c $(MYLIB) $(TYPES) $(DICT) $(DIFF) $(DESCRIPTORS)
107                  gcc $(CCFLAGS) equiv.c
108
109      extract.o:     extract.c $(BOOLEAN) $(TYPES) $(DICT)
110                  gcc $(CCFLAGS) extract.c
111
112      l2Norm2.o:     l2Norm2.c $(BOOLEAN) $(TYPES) $(ERROR) $(DICT)
113                  gcc $(CCFLAGS) l2Norm2.c
114
115      match.o:       match.c $(BOOLEAN) $(TYPES) $(PICT) $(DIFF2) $(MATCH) $(MATCHPARALLEL)
116                  gcc $(CCFLAGS) match.c
117
118      matchparallel.o: matchparallel.c $(BOOLEAN) $(TYPES) $(PICT) $(DIFF2) \
119                      $(MATCH) $(MATCHPARALLEL)
120                  gcc $(CCFLAGS) matchparallel.c
121
122      newL2.o:       newL2.c $(BOOLEAN) $(ERROR) $(TYPES) $(DICT)
123                  gcc $(CCFLAGS) newL2.c
124
125      newMatch.o:    newMatch.c $(ERROR) $(MISC) $(NEWMATCH) $(DICT) $(TYPES)
126                  gcc $(CCFLAGS) newMatch.c
127
128      recogDesc.o:   recogDesc.c $(MYLIB) $(TYPES) $(DICT) $(DIFF)
129                  gcc $(CCFLAGS) recogDesc.c
130
131      resample.o:    resample.c $(BOOLEAN) $(TYPES) $(ERROR) $(DICT)
132                  gcc $(CCFLAGS) resample.c
133
134      single.o:      single.c $(MYLIB) $(TYPES) $(DICT) $(DIFF) $(DIFF2) $(MATCH)
135                      $(MATCHPARALLEL)
136                  gcc $(CCFLAGS) single.c
137
138      sortMatrix.o:  sortMatrix.c $(ERROR) $(PICT)
139                  gcc $(CCFLAGS) sortMatrix.c

```

Jul 9 19:36 1991 anomalies.c

```

1  #include <stdio.h>
2  #include "error.h"
3  #include "types.h"
4  #include "pict.h"
5  #include "dict.h"
6  #include "diff.h"
7  #include "misc.h"
8
9  #define MAX_STRING_LEN (100)
10 #define MAX_DICTIONARIES (15)
11 #define MAX_WORDS (100)
12 #define MAX_ENTRIES (MAX_WORDS*MAX_WORDS)
13
14 typedef struct {
15     float score;
16     int x;
17     int y;
18 } *CompareTuple, CompareTupleBody;
19
20
21 int ReadInt(FILE *fp)
22 {
23     char s[MAX_STRING_LEN];
24     int x;
25
26     fgets(s, MAX_STRING_LEN, fp);
27     while (sscanf(s, "%d", &x) != 1)
28         fprintf(stderr, "ReadInt: integer expected - reenter.\n");
29     return x;
30 }
31
32 char *ReadString(FILE *fp)
33 {
34     char s[MAX_STRING_LEN];
35     char *endPtr;
36
37     fgets(s, MAX_STRING_LEN, fp);
38     endPtr = strchr(s, '\n');
39     if (endPtr != NULL)
40         *endPtr = '\0';
41     return strdup(s);
42 }
43
44 int TupleLessThan(CompareTuple *x, CompareTuple *y)
45 {
46     if ((*x)->score == (*y)->score)
47         return 0;
48     else if ((*x)->score < (*y)->score)
49         return -1;
50     else
51         return 1;
52 }

```

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```

53
54 int CountAnomalies(Dictionary d1, Dictionary d2, char *dName1, char *dName2, char
    **words, FILE *outfp)
55 {
56     CompareTupleBody scoreBodies[MAX_ENTRIES];
57     CompareTuple scores[MAX_ENTRIES];
58     Picture pict;
59     int x, y, i, j;
60     int anomalies;
61
62     pict = CompareDictionaries(d1, d2);
63
64     for (y=0, i=0; y<pict->height; ++y)
65         for (x=0; x<pict->width; ++x) {
66             CompareTuple temp;
67             /* temp = (CompareTuple) calloc(1, sizeof(CompareTupleBody));
68              if (temp == NULL)
69                  DoError("%s: cannot allocate space.\n", argv[0]);
70             */
71             temp = scoreBodies + i;
72             temp->score = *((float *) (pict->data) + x + y * pict->width);
73             temp->x = x;
74             temp->y = y;
75             scores[i] = temp;
76             ++i;
77         }
78     qsort(scores, i, sizeof(CompareTuple), TupleLessThan);
79     for (j=0, anomalies=0; j<d1->numberOfEntries; ++j)
80         if (scores[j]->x != scores[j]->y) {
81             fprintf(outfp, "%s: %s %s: %s\n", dName1, words[scores[j]->x],
82                 dName2, words[scores[j]->y]);
83             ++anomalies;
84         }
85
86     free_pict(pict);
87     return anomalies;
88 }
89
90 void main(int argc, char **argv)
91 {
92     char *outFile, *listFile;
93     int numberOfDictionaries;
94     Dictionary dictionaries[MAX_DICTIONARIES];
95     char *names[MAX_DICTIONARIES];
96     char *words[MAX_WORDS];
97     int numberOfWords;
98     FILE *listfp, *outfp;
99     int anomalies[MAX_DICTIONARIES][MAX_DICTIONARIES];
100     int i, x, y;
101
102     if (argc != 3)
103         DoError("Usage: %s listfile outfile.\n", argv[0]);
104     listFile = argv[1];
105     outFile = argv[2];
106

```

```

107     if ((listfp = fopen(listFile, "r")) == NULL)
108         DoError("Error opening file %s.\n", listFile);
109
110     /* Read in the number of words in each dictionary */
111     numberOfWords = ReadInt(listfp);
112     if (numberOfWords > MAX_WORDS)
113         DoError("%s: too many words.\n", argv[0]);
114
115     /* Read in the words */
116     for (i=0; i<numberOfWords; ++i) {
117         words[i] = ReadString(listfp);
118     }
119
120     /* Read in the number of dictionaries */
121     numberOfDictionaries = ReadInt(listfp);
122     if (numberOfDictionaries > MAX_DICTIONARIES)
123         DoError("%s: too many dictionaries.\n", argv[0]);
124
125     /* Read in the dictionaries and their names */
126     for (i=0; i<numberOfDictionaries; ++i) {
127         names[i] = ReadString(listfp);
128         dictionaries[i] = ReadDictionary(names[i]);
129     }
130
131     /* Check to see that all dictionaries have the same number of shapes as the specified number
    of words. */
132     for (i=1; i<numberOfDictionaries; ++i)
133         if (dictionaries[i]->numberOfEntries != numberOfWords)
134             DoError("Dictionary %s has wrong number of entries.\n", names[i]);
135
136     /* Write the results */
137     if ((outfp = fopen(outFile, "w")) == NULL)
138         DoError("Error opening %s for output.\n", outFile);
139     fprintf(outfp, "Words:\n");
140     for (i=0; i<numberOfWords; ++i)
141         fprintf(outfp, "%d: %s\n", i, words[i]);
142     fprintf(outfp, "\n");
143     fprintf(outfp, "Dictionaries:\n");
144     for (i=0; i<numberOfDictionaries; ++i)
145         fprintf(outfp, "%d: %s\n", i, names[i]);
146     fprintf(outfp, "\n");
147
148     /* Fill in the anomaly counts */
149     for (y=0; y<numberOfDictionaries; ++y)
150         for (x=0; x<numberOfDictionaries; ++x) {
151             anomalies[y][x] =
152             CountAnomalies(dictionaries[y], dictionaries[x], names[y], names[x], words, outfp);
153             printf("(%d,%d): %d\n", x, y, anomalies[y][x]);
154         }
155     fprintf(outfp, "\n\n");
156     fprintf(outfp, " ");
157     for (x=0; x<numberOfDictionaries; x++)
158         fprintf(outfp, "%7d ", x);
159     fprintf(outfp, "\n");

```

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```
160     for (y=0;y<numberOfDictionaries; ++y) {
161         fprintf(outfp, " %3d ", y);
162         for (x=0;x<numberOfDictionaries; ++x)
163             fprintf(outfp, "%7d ", anomalies[y][x]);
164         fprintf(outfp, "\n");
165     }
166     fclose(outfp);
167
168 }
```


Jul 31 17:14 1991 descMain.c

```

1  #include <stdio.h>
2  #include "mylib.h"
3  #include "types.h"
4  #include "dict.h"
5  #include "diff.h"
6  #include "descriptors.h"
7
8  void PrintDescriptors(Dictionary models,char *modelName,char **wordNames,
9                        int numberOfFonts,Dictionary fonts[],
10                       char **fontNames,int numberOfWords,
11                       DiffDescriptor dd)
12  {
13      int modelIndex;fontIndex;
14      int starCount,correctCount;
15      Descriptor thisDescriptor;
16      int lineCount;
17
18      printf("\f\n");
19      PrintWords(wordNames,numberOfWords);
20      lineCount = 0;
21      starCount = 0;
22      correctCount = 0;
23      for (modelIndex=0;modelIndex<numberOfWords; ++ modelIndex) {
24          printf("%s %s\n",modelName,wordNames[modelIndex]);
25          ++ lineCount;
26          for (fontIndex=0;fontIndex<numberOfFonts; ++ fontIndex) {
27              thisDescriptor =
28              ComputeDescriptor(modelIndex,models,fonts[fontIndex],numberOfWords,dd);
29              printf(" ");
30              PrintField(fontNames[fontIndex],20);
31              PrintDescriptor(thisDescriptor,&starCount,&correctCount);
32              printf("\n");
33              ++ lineCount;
34          }
35          if (lineCount>30) {
36              printf("\f\n");
37              PrintWords(wordNames,numberOfWords);
38              lineCount = 0;
39          }
40          fprintf(stdout,"There were %d mismatches ",starCount-
41                numberOfWords*numberOfFonts);
42          fprintf(stdout,"better than %d correct matches. (%6.2f%)\n",
43                numberOfWords*numberOfFonts,
44                (float)(numberOfWords*numberOfFonts)/(float)starCount);
45          fprintf(stdout,"There were %d correctly matched words out of %d. (%6.2f%)\n",
46                correctCount,numberOfWords*numberOfFonts,
47                (float)correctCount/(float)numberOfWords/numberOfFonts);
48      }
49      void main(int argc,char **argv)
50      {

```

```

51     char *listFile;
52     Dictionary models;
53     char *modelName;
54     int numberOfFonts;
55     Dictionary fonts[MAX_FONTS];
56     char *fontNames[MAX_FONTS];
57     char *wordNames[MAX_WORDS];
58     int numberOfWords;
59     float centerWeight;
60     int normalBandWidth;
61     BOOLEAN
lengthNormalize,useL2,slopeConstrain,warp,topToBottomOption,hillToValleyOption;
62     BOOLEAN separate;
63     float topToBottom,hillToValleyLocal;
64     FILE *listfp;
65     int i,x,y;
66     DiffDescriptorBody dd;
67
68     centerWeight = 1.0;
69     normalBandWidth = 20;
70     topToBottom = 1.0;
71     hillToValleyLocal = 1.0;
72     DefArg("%s","listFile",&listFile);
73     DefOption("-L2","-L2",&useL2);
74     DefOption("-slopeConstrain %f","-slopeConstrain <center weight> ",
75             &slopeConstrain,&centerWeight);
76     DefOption("-warp %f %d","-warp <center weight> <band width> ",
77             &warp,&centerWeight,&normalBandWidth);
78     DefOption("-separate","-separate",&separate);
79     DefOption("-normalize","-normalize",&lengthNormalize);
80     DefOption("-topToBottom %f","-topToBottom
<ratio>",&topToBottomOption,&topToBottom);
81     DefOption("-hillToValley %f","-hillToValley
<ratio>",&hillToValleyOption,&hillToValleyLocal);
82     ScanArgs(argc,argv);
83
84     if ((listfp = fopen(listFile,"r")) == NULL)
85         DoError("Error opening file %s.\n",listFile);
86
87     /* Read in the number of words in each dictionary */
88     numberOfWords = ReadInt(listfp);
89     if (numberOfWords > MAX_WORDS)
90         DoError("%s: too many words.\n",argv[0]);
91
92     /* Read in the words */
93     for (i=0;i<numberOfWords; ++i) {
94         wordNames[i] = ReadString(listfp);
95     }
96
97     /* Read in the model dictionary */
98     modelName = ReadString(listfp);
99     models = ReadDictionary(modelName);
100
101     /* Read in the number of dictionaries */
102     numberOfFonts = ReadInt(listfp);

```

```

103     if (numberOfFonts > MAX_FONTS)
104         DoError("%s: too many dictionaries.\n",argv[0]);
105
106     /* Read in the dictionaries and their names */
107     for (i=0;i<numberOfFonts; ++i) {
108         fontNames[i] = ReadString(listfp);
109         fonts[i] = ReadDictionary(fontNames[i]);
110     }
111
112     /* Check to see that all dictionaries have the same number of shapes as the specified number
of words. */
113     for (i=1;i<numberOfFonts; ++i)
114         if (fonts[i]->numberOfEntries < numberOfWords)
115             DoError("Dictionary %s has too few entries.\n",fontNames[i]);
116     if (models->numberOfEntries < numberOfWords)
117         DoError("Model dictionary has too few of entries.\n",NULL);
118
119
120     if (useL2) {
121         fprintf(stdout,"Using L2 on length normalized shapes.\n");
122         dd.diffType = L2;
123     }
124     else if (slopeConstrain) {
125         fprintf(stdout,"Using dynamic time warping with slope constrained to [0.5,2].\n");
126         dd.diffType = CONSTRAINED;
127         dd.separate = separate;
128         if (separate)
129             fprintf(stdout,"Top and bottom warped separately.\n");
130         else
131             fprintf(stdout,"Top and bottom warped together.\n");
132     }
133     else {
134         fprintf(stdout,"Using dynamic time warping with bandwidth %d.\n",normalBandWidth);
135         dd.diffType = WARP;
136         dd.bandWidth = normalBandWidth;
137         dd.separate = separate;
138         if (separate)
139             fprintf(stdout,"Top and bottom warped separately.\n");
140         else
141             fprintf(stdout,"Top and bottom warped together.\n");
142     }
143     if (!useL2) {
144         fprintf(stdout,"Center weight = %f.\n",centerWeight);
145         dd.centerWeight = centerWeight;
146         if (lengthNormalize) {
147             dd.lengthNormalize = TRUE;
148             fprintf(stdout,"Scores normalized by signal length.\n");
149         }
150         else
151             dd.lengthNormalize = FALSE;
152     }
153     dd.hillToValley = hillToValleyLocal;
154     dd.topToBottom = topToBottom;
155     dd.pathFP = NULL;
156

```

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```
157     fprintf(stdout, "Words:\n");
158     for (i=0; i<numberOfWords; ++ i)
159         fprintf(stdout, "%d: %s\n", i, wordNames[i]);
160     fprintf(stdout, "\n");
161     fprintf(stdout, "Model font is %s.\n", modelName);
162     fprintf(stdout, "Fonts:\n");
163     for (i=0; i<numberOfFonts; ++ i)
164         fprintf(stdout, "%d: %s\n", i, fontNames[i]);
165     fprintf(stdout, "\n");
166
167     PrintDescriptors(models, modelName, wordNames, numberOfFonts, fonts, fontNames, number
C:\Words, &dd);
168 }
```

Jul 26 13:48 1991 descriptors.c

```

1  #include <stdio.h>
2  #include "mylib.h"
3  #include "types.h"
4  #include "dict.h"
5  #include "diff.h"
6  #include "misc.h"
7  #include "descriptors.h"
8
9  typedef struct {
10     float score;
11     int word;
12 } *CompareTuple, CompareTupleBody;
13
14 int TupleLessThan(CompareTuple x, CompareTuple y)
15 {
16     if (x->score == y->score)
17         return 0;
18     else if (x->score < y->score)
19         return -1;
20     else
21         return 1;
22 }
23
24 int CompareDescriptorElements(Descriptor x, Descriptor y)
25 {
26     if (*x == *y)
27         return 0;
28     else if (*x < *y)
29         return -1;
30     else
31         return 1;
32 }
33
34 Descriptor ComputeDescriptor(int modelIndex, Dictionary models, Dictionary thisFont, int
numberOfWords,
35                             DiffDescriptor dd)
36 {
37     DescriptorElement descriptor[MAX_WORDS + 1];
38     CompareTupleBody results[MAX_WORDS];
39     int i;
40
41     for (i = 0; i < numberOfWords; ++i) {
42         results[i].score =
DiffPair(*(models->outlines + modelIndex), *(thisFont->outlines + i), dd);
43         results[i].word = i;
44     }
45     qsort(results, thisFont->numberOfEntries, sizeof(CompareTupleBody), TupleLessThan);
46     for (i = 0; i < numberOfWords; ++i) {
47         descriptor[i] = results[i].word + 1; /* Descriptor values are one greater than word indices
*/
48         if (results[i].word == modelIndex) {
49             ++i;

```

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```

50     break;
51 }
52 }
53 descriptor[i] = '\0';
54 qsort(descriptor,i,sizeof(DescriptorElement),CompareDescriptorElements);
55 return (Descriptor)strdup((char *)descriptor);
56 }
57
58 void PrintField(char *s,int w)
59 {
60     int i,l;
61     printf("%s",s);
62     l = w-strlen(s);
63     for (i=0;i<l; ++i)
64         printf(" ");
65 }
66
67 void PrintDescriptor(Descriptor d,int *starCount,int *correctCount)
68 {
69     int i=1;      /* Descriptor values are one greater than word indices */
70     int temp;
71     temp = *starCount;
72     if (*d == '\0') {
73         printf("***");
74         ++*starCount;
75     }
76     while (*d != '\0') {
77         while (i++ < *d)
78             printf(" ");
79         printf("***");
80         ++*starCount;
81         d++;
82     }
83     if (*starCount-temp == 1)
84         ++*correctCount;
85 }
86
87 void PrintWords(char **words,int numberOfWords)
88 {
89     int lengths[MAX_WORDS];
90     int i,j;
91     int maxLength = 0;
92
93     maxLength = 0;
94     for (i=0;i<numberOfWords; ++i) {
95         lengths[i] = strlen(words[i]);
96         if (lengths[i] > maxLength)
97             maxLength = lengths[i];
98     }
99
100    for (j=0;j<maxLength; ++j) {
101        printf("      ");
102        for (i=0;i<numberOfWords; ++i)
103            if (j<lengths[i])
104                printf("%c",*(words[i]+j));

```

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```
105     else
106         printf(" ");
107     printf("\n");
108 }
109 }
110
111
```

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Jul 31 17:11 1991 diff2.c

```

1  #include <stdio.h>
2  #include "boolean.h"
3  #include "types.h"
4  #include "error.h"
5  #include "pict.h"
6  #include "dict.h"
7  #include "diff.h"
8  #include "newMatch.h"
9
10
11 extern double fabs(double);
12
13 /* Dynamic programming version of DiffPair */
14 inline float DiffPair(OutlinePair one, OutlinePair two,
15                      DiffDescriptor dd)
16 {
17     hillToValley = dd->hillToValley;
18     if ((dd->separate)&&(dd->pathFP!=NULL))
19         DoError("DiffPair: separate cannot be used with pathfile option.\n",NULL);
20     switch (dd->diffType) {
21     case CONSTRAINED:
22         if (dd->pathFP != NULL)
23             return SlopeCMatchAndPath(one->top,one->bottom,one->numberOfLegs,
24                                       two->top,two->bottom,two->numberOfLegs,
25                                       dd->centerWeight,dd->lengthNormalize,dd->topToBottom,
26                                       dd->pathFP);
27         else
28             if (dd->separate)
29                 return
30                     SepSlopeCMatch(one->top,one->numberOfLegs,two->top,two->numberOfLegs,
31                                   dd->centerWeight,dd->lengthNormalize)*dd->topToBottom +
32                     SepSlopeCMatch(one->bottom,one->numberOfLegs,two->bottom,two->number
33                                   OfLegs,
34                                   dd->centerWeight,dd->lengthNormalize);
35         else
36             return SlopeCMatch(one->top,one->bottom,one->numberOfLegs,
37                               two->top,two->bottom,two->numberOfLegs,
38                               dd->centerWeight,dd->lengthNormalize,dd->topToBottom);
39         break;
40     case L2:
41         if (dd->pathFP != NULL)
42             DoError("DiffPair: L2 does not support path computation.\n",NULL);
43         else
44             return L2Compare(one,two,dd->topToBottom);
45         break;
46     case WARP:
47         if (dd->pathFP != NULL)
48             return NewMatchAndPath(one->top,one->bottom,one->numberOfLegs,
49                                   two->top,two->bottom,two->numberOfLegs,
50                                   dd->centerWeight,dd->lengthNormalize,dd->bandWidth,
51                                   dd->topToBottom,

```



```

50         dd->pathFP);
51     else
52     if (dd->separate)
53         return SepMatch(one->top,one->numberOfLegs,two->top,two->numberOfLegs,
54             dd->centerWeight,dd->lengthNormalize,dd->bandWidth)*dd->topToBottom +
55             SepMatch(one->bottom,one->numberOfLegs,two->bottom,two->numberOfLegs,
56                 dd->centerWeight,dd->lengthNormalize,dd->bandWidth);
57     else
58     return
59     NewMatch(one->top,one->bottom,one->numberOfLegs,two->top,two->bottom,
60         two->numberOfLegs,
61         dd->centerWeight,dd->lengthNormalize,dd->bandWidth,
62         dd->topToBottom);
63     break;
64     default:
65     DoError("DiffPair: internal error.\n",NULL);
66     }
67 }
68 #ifdef foo
69 inline float DiffPairAndPath(OutlinePair one, OutlinePair two,
70     float centerWeight,BOOLEAN lengthNormalize,int
71     normalBandWidth,
72     char *filename,BOOLEAN doPath)
73 {
74     FILE *fp;
75     float score;
76     if ((fp=fopen(filename,"w"))==NULL)
77         DoError("DiffPairAndMatch: error opening output file %s.\n",filename);
78     score = NewMatchAndPath(one->top,one->bottom,one->numberOfLegs,
79         two->top,two->bottom,two->numberOfLegs,
80         centerWeight,lengthNormalize,normalBandWidth,
81         fp,doPath);
82     fclose(fp);
83     return score;
84 }
85 #endif
86
87 BOOLEAN IsSymmetric(Picture pict)
88 {
89     int x,y;
90     float maxDiff = 0;
91     for (y=0;y<pict->height; ++y)
92     for (x=0;x<pict->width; ++x) {
93         float temp = fabs (((float *) (pict->data) + pict->width*y + x) -
94             ((float *) (pict->data) + pict->width*x + y));
95         if (temp > maxDiff)
96             maxDiff = temp;
97     }
98     fprintf(stderr,"maxDiff = %f.\n",maxDiff);
99     if (maxDiff > 0.01)
100         return FALSE;

```

```

99     return TRUE;
100 }
101
102 /* Given the names of two dictionary files, compute the squared difference
103  * between every pair of shapes in the cross product of the dictionaries.
104  * The result is a matrix printed to stdout. The width and height are
105  * followed by the matrix entries in row major order. The output is in
106  * ascii to facilitate reading by a Symbolics. */
107 Picture CompareDictionaries(Dictionary dict1, Dictionary dict2, DiffDescriptor dd)
108 {
109     Picture pict;
110     int x,y;
111     pict = new_pict(dict2->numberOfEntries,
112                    dict1->numberOfEntries,
113                    32);
114
115     for (y=0;y<pict->height; ++y)
116         for (x=0;x<pict->width; ++x) {
117             /* for output files when printing and match */
118             printf("----> (%d,%d) <---\n",y,x);
119             *((float *) (pict->data) + pict->width*y + x) =
120                 DiffPair(*(dict1->outlines + y),
121                        *(dict2->outlines + x),
122                        dd);
123         }
124     if (!IsSymmetric(pict))
125         fprintf(stderr, "Matrix is not symmetric.\n");
126     return pict;
127 }
128
129 void WritePictureAsAscii(Picture pict, char *filename,
130                        char *info1, char *info2)
131 {
132     FILE *fp;
133     int x,y;
134     int count;
135
136     if ((fp = fopen(filename, "w")) == NULL)
137         DoError("WritePictureAsAscii: error opening output file\n", NULL);
138     fprintf(fp, "%s\n", info1);
139     fprintf(fp, "%s\n", info2);
140     fprintf(fp, "#\n");
141     fprintf(fp, "%d\n%d\n", pict->width, pict->height);
142     fprintf(fp, "%3s ", "");
143     for (x = 0; x < pict->width; x++)
144         fprintf(fp, "%7d ", x);
145     fprintf(fp, "\n");
146     for (y=0;y<pict->height; ++y) {
147         fprintf(fp, " %3d ", y);
148         count = 1;
149         for (x=0;x<pict->width; ++x) {
150             fprintf(fp, "%7.3f ", (((float *) pict->data) + ++));
151             /* if ((pict->width > 10) && (!(count++ % 10)))
152                fprintf(fp, "\n");
153             */ }

```

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```
154     fprintf(fp, "\n");
155     }
156     fclose(fp);
157 }
```

Section C

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Jul 22 15:21 1991 dmain.c

```

1  #include <stdio.h>
2  #include <math.h>
3  #include <values.h>
4  #include "boolean.h"
5  #include "types.h"
6  #include "pict.h"
7  #include "dict.h"
8  #include "diff.h"
9  #include "match.h"
10 #include "matchparallel.h"
11
12
13 void main(int argc, char **argv)
14 {
15     Picture pict;
16     char *infile1, *infile2, *outfile, *format;
17     Dictionary dict1, dict2;
18
19     if (argc != 5) {
20         printf("Usage:\n");
21         printf(" %s infile1 infile2 outfile format\n", argv[0]);
22         printf(" where format is either ascii or pict.\n");
23         exit(-1);
24     }
25
26     infile1 = argv[1];
27     infile2 = argv[2];
28     outfile = argv[3];
29     format = argv[4];
30
31     dict1 = ReadDictionary(infile1);
32     dict2 = ReadDictionary(infile2);
33     pict = CompareDictionaries(dict1, dict2, 1, TRUE, 20, FALSE);
34     if (!strcmp(format, "pict"))
35         write_pict(outfile, pict);
36     else
37         WritePictureAsAscii(pict, outfile, dict1->infoString, dict2->infoString);
38 }

```

Section C

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Aug 15 20:20 1991 drawBlobs.c

```

1  #include <stdio.h>
2  #include "mylib.h"
3  #include "types.h"
4  #include "dict.h"
5
6  #define WIDTH (800)
7  #define H_MARGIN (20)
8  #define V_MARGIN (60)
9  #define H_SPACING (20)
10 #define V_SPACING (150) /* Must be greater than 2*X_HEIGHT */
11 #define X_HEIGHT (17)
12
13 extern int irint(double);
14
15 void DrawVLine(Picture pict,int x,int yt,int yb)
16 {
17     int i;
18     for (i=yt;i<yb; ++i)
19         WritePixel(pict,x,i,1);
20 }
21
22 void DrawOutline(Picture pict,OutlinePair o,int x,int y)
23 {
24     int i,top,bottom;
25     for (i=0;i<o->numberOfLegs; ++i) {
26         top = irint(-(o->top+i)*X_HEIGHT);
27         bottom = irint((o->bottom+i)*X_HEIGHT+X_HEIGHT);
28         DrawVLine(pict,i+x,top+y,bottom+y);
29     }
30 }
31
32 int main(int argc,char **argv)
33 {
34     char *infile,*outfile;
35     Dictionary dict;
36     Picture pict;
37     int i,totalLegs,totalLines;
38     int x,y,newX;
39
40     DefArg("%s %s","infile outfile",&infile,&outfile);
41     ScanArgs(argc,argv);
42
43     dict = ReadDictionary(infile);
44
45     for (i=0,totalLegs=H_MARGIN,totalLines=V_MARGIN;i<dict->numberOfEntries; ++i) {
46         OutlinePair thisOutline = *(dict->outlines+i);
47         totalLegs += thisOutline->numberOfLegs + H_SPACING;
48         if (totalLegs > WIDTH) {
49             totalLines += V_SPACING;
50             totalLegs = H_MARGIN + thisOutline->numberOfLegs + H_SPACING;
51             if (totalLegs > WIDTH)

```

Section C

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```

52         DoError("%s: Shape is too wide.\n",argv[0]);
53     }
54 }
55
56 pict = new_pict(WIDTH,totalLines+V_MARGIN*2,1);
57
58 for (i=0,x=H_MARGIN,y=V_MARGIN;i<dict->numberOfEntries; ++ i) {
59     OutlinePair thisOutline = *(dict->outlines+i);
60
61     newX = x + thisOutline->numberOfLegs + H_SPACING;
62     if (newX > WIDTH) {
63         newX = H_MARGIN + thisOutline->numberOfLegs + H_SPACING;
64         x = H_MARGIN;
65         y += V_SPACING;
66     }
67
68     DrawOutline(pict,*(dict->outlines+i),x,y);
69
70     x = newX;
71 }
72
73 write_pict(outfile,pict);
74 }

```

Jul 26 16:47 1991 equiv.c

```

1  #include <stdio.h>
2  #include "mylib.h"
3  #include "types.h"
4  #include "dict.h"
5  #include "diff.h"
6  #include "descriptors.h"
7
8  void PrintEquivalenceClasses(int numberOfWords,char **wordNames,
9                             int numberOfFonts,Dictionary fonts[],char **fontNames,
10                             DiffDescriptor dd)
11  {
12      Descriptor descriptors[MAX_FONTS*MAX_FONTS];
13      int matchesWord[MAX_WORDS];
14      int word,font1,font2,i;
15      int totalDifferent,totalWords;
16      int numberOfPairs;
17
18      for (word=0;word<numberOfWords; ++ word) {
19          for (font1=0,numberOfPairs=0;font1<numberOfFonts; ++ font1)
20              for (font2=0;font2<font1; ++ font2)
21                  descriptors[numberOfPairs++] = ComputeDescriptor(word,fonts[font1],
22                                                                    fonts[font2],numberOfWords,dd);
23          for (i=0;i<numberOfWords; ++ i)
24              matchesWord[i] = 0;
25          for (i=0;i<numberOfPairs; ++ i) {
26              Descriptor p;
27              p = descriptors[i];
28              while (*p!='\0')
29                  matchesWord[*p++ - 1]++;
30          }
31          for (i=0,totalDifferent=0,totalWords=0;i<numberOfWords; ++ i) {
32              if (matchesWord[i])
33                  ++ totalDifferent;
34              totalWords += matchesWord[i];
35          }
36          printf("%20s:\t\t%6d %6.2f %6d %6.2f\n",wordNames[word],totalWords,
37                (float)totalWords/numberOfPairs,totalDifferent,
38                (float)totalDifferent/(float)totalWords*numberOfPairs);
39          fprintf(stderr,"%20s:\t\t%6d %6.2f %6d %6.2f\n",wordNames[word],totalWords,
40                (float)totalWords/numberOfPairs,totalDifferent,
41                (float)totalDifferent/(float)totalWords*numberOfPairs);
42      }
43  }
44
45
46  void main(int argc,char **argv)
47  {
48      char *listFile;
49      int numberOfFonts;
50      Dictionary fonts[MAX_FONTS];
51      char *fontNames[MAX_FONTS];
52      char *wordNames[MAX_WORDS];

```

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```

53     int numberOfWords;
54     float centerWeight;
55     int normalBandWidth;
56     BOOLEAN
lengthNormalize,useL2,slopeConstrain,warp,topToBottomOption,hillToValleyOption;
57     float topToBottom,hillToValleyLocal;
58     FILE *listfp;
59     int i,x,y;
60     DiffDescriptorBody dd;
61
62     centerWeight = 1.0;
63     normalBandWidth = 20;
64     topToBottom = 1.0;
65     hillToValleyLocal = 1.0;
66     DefArg("%s","listFile",&listFile);
67     DefOption("-L2","-L2",&useL2);
68     DefOption("-slopeConstrain %f","-slopeConstrain <center weight> ",
69             &slopeConstrain,&centerWeight);
70     DefOption("-warp %f %d","-warp <center weight> <band width> ",
71             &warp,&centerWeight,&normalBandWidth);
72     DefOption("-normalize","-normalize",&lengthNormalize);
73     DefOption("-topToBottom %f","-topToBottom
<ratio>",&topToBottomOption,&topToBottom);
74     DefOption("-hillToValley %f","-hillToValley
<ratio>",&hillToValleyOption,&hillToValleyLocal);
75     ScanArgs(argc,argv);
76
77     if ((listfp = fopen(listFile,"r")) == NULL)
78         DoError("Error opening file %s.\n",listFile);
79
80     /* Read in the number of words in each dictionary */
81     numberOfWords = ReadInt(listfp);
82     if (numberOfWords > MAX_WORDS)
83         DoError("%s: too many words.\n",argv[0]);
84
85     /* Read in the words */
86     for (i=0;i<numberOfWords; ++i) {
87         wordNames[i] = ReadString(listfp);
88     }
89
90     /* Read in the number of dictionaries */
91     numberOfFonts = ReadInt(listfp);
92     if (numberOfFonts > MAX_FONTS)
93         DoError("%s: too many dictionaries.\n",argv[0]);
94
95     /* Read in the dictionaries and their names */
96     for (i=0;i<numberOfFonts; ++i) {
97         fontNames[i] = ReadString(listfp);
98         fonts[i] = ReadDictionary(fontNames[i]);
99     }
100
101     /* Check to see that all dictionaries have the same number of shapes as the specified number
of words. */
102     for (i=1;i<numberOfFonts; ++i)
103         if (fonts[i]->numberOfEntries < numberOfWords)

```


Section C

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```

104     DoError("Dictionary %s has too few entries.\n",fontNames[i]);
105
106     if (useL2) {
107         printf("Using L2 on length normalized shapes.\n");
108         dd.diffType = L2;
109     }
110     else if (slopeConstrain) {
111         printf("Using dynamic time warping with slope constrained to [0.5,2].\n");
112         dd.diffType = CONSTRAINED;
113     }
114     else {
115         printf("Using dynamic time warping with bandwidth %d.\n",normalBandWidth);
116         dd.diffType = WARP;
117         dd.bandWidth = normalBandWidth;
118     }
119     if (!useL2) {
120         printf("Center weight = %f.\n",centerWeight);
121         dd.centerWeight = centerWeight;
122         if (lengthNormalize) {
123             dd.lengthNormalize = TRUE;
124             printf("Scores normalized by signal length.\n");
125         }
126         else
127             dd.lengthNormalize = FALSE;
128     }
129     dd.hillToValley = hillToValleyLocal;
130     dd.topToBottom = topToBottom;
131     dd.pathFP = NULL;
132
133     printf("Fonts:\n");
134     for (i=0;i<numberOfFonts; ++i)
135         printf(" %d: %s\n",i,fontNames[i]);
136     printf("\n");
137
138     PrintEquivalenceClasses(numberOfWords,wordNames,numberOfFonts,fonts,fontNames,&d);
139 }
140
141
142
143
144
145
146

```

Jul 3 14:31 1991 extract.c

```

1  #include <stdio.h>
2  #include <math.h>
3  #include <values.h>
4  #include "boolean.h"
5  #include "types.h"
6  #include "dict.h"
7
8  #define MAX_STRING_LEN 100
9  int ReadInt(FILE *fp)
10 {
11     char s[MAX_STRING_LEN];
12     int x;
13
14     fgets(s,MAX_STRING_LEN,fp);
15     while (sscanf(s,"%d",&x)!= 1)
16         fprintf(stderr,"ReadInt: integer expected - reenter.\n");
17     return x;
18 }
19
20 void main(int argc,char **argv)
21 {
22     char *infile,*listFile,*outfile;
23     Dictionary dict1,dict2;
24     int i;
25     int numberOfEntries;
26     FILE *fp;
27
28     if (argc != 4) {
29         printf("Usage:\n");
30         printf(" %s infile listfile outfile\n",argv[0]);
31         exit(-1);
32     }
33
34     infile = argv[1];
35     listFile = argv[2];
36     outfile = argv[3];
37
38     dict1 = ReadDictionary(infile);
39
40     if ((fp=fopen(listFile,"r"))== NULL)
41         DoError("%s: error reading list file.\n",argv[0]);
42
43     numberOfEntries = ReadInt(fp);
44     if (numberOfEntries < 0)
45         DoError("%s: list file must have a positive number of elements.\n",argv[0]);
46     printf("Copying %d shapes.\n",numberOfEntries);
47
48     dict2 = NewDict(numberOfEntries);
49
50     dict2->infoString = dict1->infoString;
51     for (i=0;i<numberOfEntries; ++i) {
52         int shape;

```

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```
53     shape = ReadInt(fp);
54     if ((shape < 0) || (shape >= dict1->numberOfEntries))
55         DoError("%s: bad shape index.\n", argv[0]);
56     *(dict2->outlines+i) = *(dict1->outlines+shape);
57     *(dict2->rawOutlines+i) = *(dict1->rawOutlines+shape);
58 }
59 fclose(fp);
60 WriteDictionary(dict2,outfile);
61
62 }
```

Section C

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Jun 14 16:12 1991 l2Norm.c

```

1  #include <stdio.h>
2  #include <values.h>
3  #include <string.h>
4  #include "boolean.h"
5  #include "types.h"
6  #include "error.h"
7  #include "dict.h"
8
9  float L2Norm(OutlinePair signal, int startOffset,
10             OutlinePair model)
11  {
12      float *top1,*top2,*bottom1,*bottom2;
13      int i,overlap;
14      float sum;
15      float temp;
16
17      if ((startOffset < 0) ||
18          (startOffset + model->numberOfLegs > signal->numberOfLegs))
19          DoError("L2Norm: the model must overlap the signal.\n",NULL);
20
21      top1 = signal->top + startOffset;
22      top2 = model->top;
23      bottom1 = signal->bottom + startOffset;
24      bottom2 = model->bottom;
25
26      overlap = signal->numberOfLegs - startOffset;
27      if (overlap > model->numberOfLegs)
28          overlap = model->numberOfLegs;
29
30      for (i=0,sum=0;i<overlap;++i) {
31          temp = *top1++ - *top2++;
32          sum += temp * temp;
33          temp = *bottom1++ - *bottom2++;
34          sum += temp * temp;
35      }
36
37      return sum;
38  }
39
40  OutlinePair LookupShape(char c, Dictionary models)
41  {
42      /* dictionary file has the following order:
43       ABCDEFGHIJKLMNOPQRSTUVWXYZ
44       abcdefghijklmnopqrstuvwxyz
45       0123456789
46
47       */
48      int shapelIndex;
49      if ((c >= 'a' && c <= 'z'))
50          shapelIndex = c - 'a';
51      else if (c == ',')
52          shapelIndex = 26;

```

```

53     else if (c == '.')
54         shapeIndex = 27;
55     else
56         DoError("LookupShape: have no shape one of the characters.\n",NULL);
57     return *(models->outlines + shapeIndex);
58 }
59
60
61 #define MAX_STRING_LENGTH 30
62 #define MAX_SHIFT 10
63 #define MAX_OVERLAP 5
64 float L2CompareWithString(OutlinePair signal, char *string,
65                           Dictionary models)
66 {
67     float *costMatrix;
68     int *pathMatrix;
69     int numberOfChars;
70     int letterIndex, startOffset;
71     float *cursor;
72     int left;
73     int right;
74     OutlinePair modelShapes[MAX_STRING_LENGTH];
75     char *charCursor;
76     float minValue;
77     float temp;
78     int i, oldLeft, oldRight, minIndex;;
79
80     /* Make sure input string is not too long. */
81     numberOfChars = strlen(string);
82     if (numberOfChars >= MAX_STRING_LENGTH)
83         DoError("L2CompareWithString: string is too long.\n",NULL);
84
85     /* Allocate space for dynamic programming array. */
86     /* For now, be a space hog. */
87     costMatrix = (float *)calloc(signal->numberOfLegs*numberOfChars,
88                                 sizeof(float));
89     pathMatrix = (int *)calloc(signal->numberOfLegs*numberOfChars,
90                               sizeof(int));
91     if ((costMatrix == NULL) || (pathMatrix == NULL))
92         DoError("L2CompareWithString: cannot allocate space.\n",NULL);
93
94     /* Lookup the shapes corresponding to the characters in the string. */
95     charCursor = string;
96     for (i=0; i<numberOfChars; ++i)
97         modelShapes[i] = LookupShape(*charCursor++, models);
98
99     /* Since the cost matrix is larger than the region containing valid
100    * alignments, first fill in the array with large costs. Later, some
101    * of these will be overwritten. */
102     cursor = costMatrix;
103     for (i=0; i<signal->numberOfLegs*numberOfChars; ++i)
104         *cursor++ = MAXFLOAT;
105
106     /* Fill in leftmost column */
107     left = 0;

```

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```

108     right = MAX_SHIFT;
109     for (startOffset=left; startOffset<right; ++startOffset)
110         if (startOffset + modelShapes[0]->numberOfLegs <=
111             signal->numberOfLegs)
112             *(costMatrix+startOffset*numberOfChars) =
113                 L2Norm(signal, startOffset, modelShapes[0]);
114
115     /* Now do the rest of the columns */
116     for (letterIndex = 1; letterIndex < numberOfChars; ++letterIndex) {
117         oldLeft = left;
118         oldRight = right;
119         left += modelShapes[letterIndex-1]->numberOfLegs;
120         right += modelShapes[letterIndex-1]->numberOfLegs + MAX_SHIFT;
121         for (startOffset=left; startOffset<right; ++startOffset) {
122             if (startOffset + modelShapes[letterIndex]->numberOfLegs <=
123                 signal->numberOfLegs) {
124                 temp = L2Norm(signal, startOffset, modelShapes[letterIndex]);
125
126             /* This could be made quite a bit faster since for each start offset,
127              * we just add an element to the set we are minimizing over. */
128             minValue = MAXFLOAT;
129             /* *(costMatrix+oldLeft*numberOfChars+letterIndex-1); */
130             minIndex = oldLeft;
131             for (i=oldLeft; (i<oldRight)&&(i<startOffset); ++i) {
132                 float temp2;
133                 temp2 = *(costMatrix+i*numberOfChars+letterIndex-1);
134                 if (temp2 < minValue) {
135                     minIndex = i;
136                     minValue = temp2;
137                 }
138             }
139             *(costMatrix+startOffset*numberOfChars+letterIndex) =
140                 minValue + temp;
141             *(pathMatrix+startOffset*numberOfChars+letterIndex) =
142                 minIndex;
143             } /* End of if */
144
145         } /* for startOffset */
146     } /* for letterIndex */
147
148     /* Now that all the costs have been filled in, find the cheapest */
149     if (right-1+modelShapes[numberOfChars-1]->numberOfLegs + MAX_SHIFT <
150         signal->numberOfLegs)
151         /* In this case, the chain of letter shapes does not span the signal. */
152         minValue = MAXFLOAT;
153     else {
154         minValue = MAXFLOAT;
155         minIndex = left;
156         for (i=left; (i<right)&&(i<signal->numberOfLegs); ++i) {
157             float temp2;
158             temp2 = *(costMatrix+i*numberOfChars+numberOfChars-1);
159             if (temp2 < minValue) {
160                 minIndex = i;
161                 minValue = temp2;
162             }

```

```

163     }
164     }
165
166     free(costMatrix);
167     free(pathMatrix);
168     return minValue;
169 }
170
171 void PrintPath(int *pm, int width, int height, int index)
172 {
173     int i;
174     for (i=width-1; i>=0; --i) {
175         printf("%d ", index);
176         index = *(pm+index*width+i);
177     }
178     printf("\n");
179 }
180
181 void PrintMatrix(float *m, int width, int height)
182 {
183     int i;
184     int j;
185     for (i=0; i<height; ++i) {
186         printf("%d: ", i);
187         for (j=0; j<width; ++j)
188             printf("%6.2e ", *m++);
189         printf("\n");
190     }
191 }
192
193 typedef struct CTuple {
194     int index;
195     float value;
196 } CompareTuple;
197
198 int TupleLessThan(CompareTuple *t1, CompareTuple *t2)
199 {
200     return t1->value > t2->value;
201 }
202
203 void L2CompareDictToString(Dictionary unknownDict,
204                             char *string,
205                             Dictionary modelDict,
206                             BOOLEAN isBatch)
207 {
208     CompareTuple *results;
209     int i;
210
211     if ((results = (CompareTuple *)calloc(unknownDict->numberOfEntries,
212                                           sizeof(CompareTuple))) ==
213         NULL)
214         DoError("L2CompareDictToString: cannot allocate space.\n", NULL);
215
216     for (i=0; i<unknownDict->numberOfEntries; ++i) {
217         (*(results+i)).index = i;

```

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```

218     (*(results+i)).value = L2CompareWithString(*(unknownDict->outlines+i),
219                                             string,
220                                             modelDict);
221 }
222
223 qsort(results,
224       unknownDict->numberOfEntries,
225       sizeof(CompareTuple),
226       TupleLessThan);
227
228 if (isBatch) {
229     printf("%d(%f)\n",(*results).index,(*results).value);
230 }
231 else {
232     printf("\n");
233     for (i=0;(i<5)&&(i<unknownDict->numberOfEntries); ++i)
234         printf("%d: %f\n",(*results+i).index,(*results+i).value);
235     printf("\n");
236 }
237
238 free(results);
239 }
240
241 void main(int argc,char **argv)
242 {
243     char *unknowns,*models;
244     char s[MAX_STRING_LENGTH+1];
245     Dictionary unknownDict, modelDict;
246     int selection;
247     char *crPointer;
248     BOOLEAN done = FALSE;
249     BOOLEAN batch;
250     char *words;
251
252     if (argc != 3 && argc != 4) {
253         printf("Usage:\n");
254         printf(" %s <unknowns> <alphabet> [<batch wordlist>]\n",argv[0]);
255         printf(" If the batch file is not specified, the program runs\n");
256         printf(" in interactive mode.\n");
257         exit(-1);
258     }
259
260     unknowns = argv[1];
261     models = argv[2];
262     if (argc == 4) {
263         batch = TRUE;
264         words = argv[3];
265     } else
266         batch = FALSE;
267
268     unknownDict = ReadDictionary(unknowns);
269     modelDict = ReadDictionary(models);
270
271     if (batch) {
272         FILE *fp;

```


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```

273     if ((fp = fopen(words, "r")) == NULL)
274         DoError("l2Norm: can't open input file %s.\n", words);
275     while (!done) {
276         fgets(s, MAX_STRING_LENGTH, fp);
277         if ((s[0] == '\0') || (s[0] == '\n'))
278             done = TRUE;
279         else {
280             crPointer = strchr(s, '\n');
281             if (crPointer != NULL)
282                 *crPointer = '\0';
283             printf("%s: ", s);
284             L2CompareDictToString(unknownDict, s, modelDict, TRUE);
285         }
286     }
287 }
288 else {
289     while (!done) {
290         printf("Enter a word to search for: ");
291         fgets(s, MAX_STRING_LENGTH, stdin);
292         if ((s[0] == '\0') || (s[0] == '\n'))
293             done = TRUE;
294         else {
295             crPointer = strchr(s, '\n');
296             if (crPointer != NULL)
297                 *crPointer = '\0';
298             printf("Comparing shape %s to the image\n", s);
299             L2CompareDictToString(unknownDict, s, modelDict, FALSE);
300         }
301     }
302 }
303 }
304

```

Section C

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Jun 18 17:00 1991 l2Norm2.c

```

1  #include <stdio.h>
2  #include <values.h>
3  #include <string.h>
4  #include "boolean.h"
5  #include "types.h"
6  #include "error.h"
7  #include "dict.h"
8
9  #define MAX_STRING_LENGTH 30
10 #define MAX_SIGNAL_LENGTH 300
11 #define MAX_SHIFT 10
12
13 #define MIN(a,b) ((a)<(b)?(a):(b))
14 #define MAX(a,b) ((a)>(b)?(a):(b))
15
16 typedef struct {
17     int numberOfSymbols;
18     int signalLength;
19     float *costs;
20 } *CorrelationSet, CorrelationSetBody;
21
22 CorrelationSet NewCorrelationSet(int numberOfSymbols, int signalLength)
23 {
24     CorrelationSet temp;
25     if ((temp = (CorrelationSet) calloc(1, sizeof(CorrelationSetBody))) == NULL)
26         DoError("NewCorrelationSet: cannot allocate space.\n", NULL);
27     temp->numberOfSymbols = numberOfSymbols;
28     temp->signalLength = signalLength;
29     if ((temp->costs = (float *) calloc(numberOfSymbols*signalLength, sizeof(float))) == NULL)
30         DoError("NewCorrelationSet: cannot allocate space.\n", NULL);
31     return temp;
32 }
33
34 #ifdef foo
35 float CorrelationValue(CorrelationSet c, int symbol, int offset)
36 {
37     return *(c->costs + symbol*c->signalLength + offset);
38 }
39
40 void SetCorrelationValue(CorrelationSet c, int symbol, int offset, float value)
41 {
42     *(c->costs + symbol*c->signalLength + offset) = value;
43 }
44 #endif
45 #define CorrelationValue(c,s,o) (*(c->costs + (s)*(c->signalLength + (o))))
46 #define SetCorrelationValue(c,s,o,v) (*(c->costs + (s)*(c->signalLength + (o))) = (v))
47
48 int CorrelationSetSize(CorrelationSet c)
49 {
50     return c->numberOfSymbols;
51 }
52

```

```

53 int CorrelationSetWidth(CorrelationSet c)
54 {
55     return c->signalLength;
56 }
57
58 void PrintCorrelation(CorrelationSet c,int character)
59 {
60     int i;
61
62     for (i=0;i<c->signalLength; ++ i) {
63         printf("%d:%6.2f\n",i,(c->costs+character*c->signalLength+i));
64     }
65     printf("\n");
66 }
67
68 float L2Norm(OutlinePair signal, int startOffset,
69             OutlinePair model)
70 {
71     float *top1,*top2,*bottom1,*bottom2;
72     int i,overlap;
73     float sum;
74     float temp;
75
76     if ((startOffset < 0) ||
77         (startOffset + model->numberOfLegs > signal->numberOfLegs))
78         DoError("L2Norm: the model must overlap the signal.\n",NULL);
79
80     top1 = signal->top+startOffset;
81     top2 = model->top;
82     bottom1 = signal->bottom+startOffset;
83     bottom2 = model->bottom;
84
85     overlap = signal->numberOfLegs - startOffset;
86     if (overlap > model->numberOfLegs)
87         overlap = model->numberOfLegs;
88
89     for (i=0,sum=0;i<overlap; ++ i) {
90         temp = *top1++ - *top2++;
91         sum += temp * temp;
92         temp = *bottom1++ - *bottom2++;
93         sum += temp * temp;
94     }
95
96     return sum;
97 }
98
99 CorrelationSet PreProcessSignalWithChars(OutlinePair signal,Dictionary charDict)
100 {
101     CorrelationSet cSet;
102     int thisChar,offset;
103     OutlinePair charSignal;
104
105     cSet = NewCorrelationSet(charDict->numberOfEntries,signal->numberOfLegs);
106
107     for (thisChar = 0; thisChar < charDict->numberOfEntries; ++ thisChar) {

```

```

108     charSignal = *(charDict->outlines+thisChar);
109     for (offset = 0; offset < signal->numberOfLegs-charSignal->numberOfLegs+1;
        ++offset)
110         SetCorrelationValue(cSet,thisChar,offset,L2Norm(signal,offset,charSignal));
111     }
112     return cSet;
113 }
114
115 CorrelationSet *PreProcessDictionaryWithChars(Dictionary signalDict,Dictionary charDict)
116 {
117     CorrelationSet *correlationSets;
118     int thisWord;
119
120     correlationSets = (CorrelationSet
        *)calloc(signalDict->numberOfEntries,sizeof(CorrelationSet));
121     if (correlationSets == NULL)
122         DoError("PreProcessDictionary: cannot allocate space.\n",NULL);
123     for (thisWord = 0; thisWord < signalDict->numberOfEntries; ++thisWord) {
124         *(correlationSets+thisWord) =
            PreProcessSignalWithChars(*(signalDict->outlines+thisWord),charDict);
125         printf("%d ",thisWord);
126     }
127     return correlationSets;
128 }
129
130 CorrelationSet PreProcessSignalWithBlanks(OutlinePair signal)
131 {
132     CorrelationSet cSet;
133     int blankWidth,offset;
134     int numberOfLegs = signal->numberOfLegs;
135
136     cSet = NewCorrelationSet(MAX_SHIFT,numberOfLegs);
137
138     for (offset = 0; offset < numberOfLegs; ++offset) {
139         SetCorrelationValue(cSet,0,offset,0);
140     }
141     for (offset = 0; offset < numberOfLegs; ++offset) {
142         float top,bottom;
143         top = *(signal->top+offset);
144         bottom = *(signal->bottom+offset);
145         SetCorrelationValue(cSet,1,offset,top*top+bottom*bottom);
146     }
147     for (blankWidth = 2; blankWidth < MAX_SHIFT; ++blankWidth) {
148         for (offset = 0; offset < numberOfLegs-blankWidth+1; ++offset) {
149             float top,bottom,temp;
150             top = *(signal->top+offset+blankWidth-1);
151             bottom = *(signal->bottom+offset+blankWidth-1);
152             temp = top*top+bottom*bottom+CorrelationValue(cSet,blankWidth-1,offset);
153             SetCorrelationValue(cSet,blankWidth,offset,temp);
154         }
155     }
156     return cSet;
157 }
158
159 CorrelationSet *PreProcessDictionaryWithBlanks(Dictionary signalDict)

```

```

160 {
161     CorrelationSet *correlations;
162     int thisWord;
163
164     correlations = (CorrelationSet
165         *)calloc(signalDict->numberOfEntries,sizeof(CorrelationSet));
166
167     for (thisWord = 0; thisWord < signalDict->numberOfEntries; ++ thisWord) {
168         *(correlations+thisWord) =
169         PreProcessSignalWithBlanks(*(signalDict->outlines+thisWord));
170         printf("%d ",thisWord);
171     }
172     return correlations;
173 }
174
175 int LookupShapeIndex(char c, Dictionary models)
176 {
177     /* dictionary file has the following order:
178     ABCDEFGHIJKLMNOPQRSTUVWXYZ
179     abcdefghijklmnopqrstuvwxyz
180     0123456789
181     */
182     int shapeIndex;
183     if ((c>='a'&&c<='z'))
184         shapeIndex = c-'a';
185     else if (c == ',')
186         shapeIndex = 26;
187     else if (c == '.')
188         shapeIndex = 27;
189     else
190         DoError("LookupShape: have no shape one of the characters.\n",NULL);
191     return shapeIndex;
192 }
193
194 float L2CompareWithString(int signalIndex,
195     char *string,
196     CorrelationSet charCorrelations,
197     CorrelationSet blankCorrelations,
198     Dictionary signalDict,
199     Dictionary models)
200 {
201     /* Allocate space for dynamic programming array. */
202     /* For now, be a space hog. */
203     float costMatrix[MAX_SIGNAL_LENGTH][MAX_STRING_LENGTH];
204     int pathMatrix[MAX_SIGNAL_LENGTH][MAX_STRING_LENGTH];
205     char *charCursor;
206     OutlinePair modelShapes[MAX_STRING_LENGTH];
207     int modelIndices[MAX_STRING_LENGTH];
208     int numberOfChars;
209
210     int letterIndex, startOffset;
211     int left,right;
212     int searchLeft,searchRight,rightEdge;

```

```

213     float minValue;
214     float temp;
215     int i,oldLeft,oldRight,minIndex;
216     int signalLength;
217
218     signalLength = (*(signalDict->outlines+signalIndex))->numberOfLegs;
219
220     /* Make sure input string is not too long. */
221     numberOfChars = strlen(string);
222     if (numberOfChars >= MAX_STRING_LENGTH)
223         DoError("L2CompareWithString: string is too long.\n",NULL);
224
225     /* Make sure signal is not too long. */
226     if (signalLength >= MAX_SIGNAL_LENGTH)
227         DoError("L2CompareWithString: signal is too long.\n",NULL);
228
229     /* Lookup the indices of the signals corresponding to the characters in the string. */
230     charCursor = string;
231     for (i=0;i<numberOfChars; ++i) {
232         modelIndices[i] = LookupShapeIndex(*charCursor++ ,models);
233         modelShapes[i] = *(models->outlines+modelIndices[i]);
234     }
235
236     /* Since the cost matrix is larger than the region containing valid
237      * alignments, first fill in the array with large costs. Later, some
238      * of these will be overwritten. */
239     /* WARNING: does MAXFLOAT + smallFloat == MAXFLOAT or does it roll? */
240     {
241         float *cursor;
242         cursor = &(costMatrix[0][0]);
243         for (i=0;i<MAX_SIGNAL_LENGTH*MAX_STRING_LENGTH; ++i)
244             *cursor++ = MAXFLOAT;
245     }
246
247     /* Fill in leftmost column */
248     left = 0;
249     right = MIN(MAX_SHIFT,signalLength-modelShapes[0]->numberOfLegs);
250     for (startOffset=left;startOffset<right; ++startOffset)
251         costMatrix[startOffset][0] = CorrelationValue(blankCorrelations,startOffset,startOffset)
252         +
253             CorrelationValue(charCorrelations,modelIndices[0],startOffset);
254
255     /* Now do the rest of the columns */
256     for (letterIndex = 1; letterIndex < numberOfChars; ++letterIndex) {
257         oldLeft = left;
258         oldRight = right;
259         left += modelShapes[letterIndex-1]->numberOfLegs;
260         /* If string of characters is too long for this signal, abort by returning a large cost. */
261         if (left >= signalLength)
262             return MAXFLOAT;
263         right += modelShapes[letterIndex-1]->numberOfLegs + MAX_SHIFT;
264         right = MIN(right,signalLength-modelShapes[letterIndex]->numberOfLegs + 1);
265
266         for (startOffset=left;startOffset<right; ++startOffset) {
267             temp = CorrelationValue(charCorrelations,modelIndices[letterIndex],startOffset);

```

```

267
268 /* This could be made quite a bit faster since for each start offset,
269 * we just add an element to the set we are minimizing over. */
270
271 searchLeft = startOffset-modelShapes[letterIndex-1]->numberOfLegs-MAX_SHIFT;
272 searchLeft = MAX(searchLeft,oldLeft);
273 rightEdge = searchLeft+modelShapes[letterIndex-1]->numberOfLegs;
274 searchRight = startOffset-modelShapes[letterIndex-1]->numberOfLegs;
275 searchRight = MIN(searchRight,oldRight);
276
277 minIndex = searchLeft;
278 minVal = costMatrix[searchLeft][letterIndex-1] +
279 CorrelationValue(blankCorrelations,startOffset-rightEdge,rightEdge);
280
281 for (i=searchLeft;i<searchRight; ++i, ++rightEdge) {
282     float temp;
283     temp = costMatrix[i][letterIndex-1] +
284     CorrelationValue(blankCorrelations,startOffset-rightEdge,rightEdge);
285     if (temp < minVal) {
286         minIndex = i;
287         minVal = temp;
288     }
289 }
290
291 costMatrix[startOffset][letterIndex] = minVal+temp;
292 pathMatrix[startOffset][letterIndex] = minIndex;
293 } /* for startOffset */
294 } /* for letterIndex */
295
296
297 /* fill in the costs for blanks at the end of the word */
298 rightEdge = left+modelShapes[letterIndex-1]->numberOfLegs;
299 for (startOffset=left;startOffset<right; ++startOffset, ++rightEdge) {
300     if (rightEdge+MAX_SHIFT >= signalLength) {
301         costMatrix[startOffset][letterIndex-1] +=
302         CorrelationValue(blankCorrelations,signalLength-1-rightEdge,rightEdge);
303     }
304     else {
305         /* this chain of letters does not span the word */
306         costMatrix[startOffset][letterIndex-1] = MAXFLOAT;
307     }
308 }
309
310 /* keep minIndex for debugging purposes */
311 minIndex = left;
312 minVal = costMatrix[left][letterIndex-1];
313 for (i=left;i<right; ++i) {
314     float temp;
315     temp = costMatrix[i][letterIndex-1];
316     if (temp < minVal) {
317         minIndex = i;
318         minVal = temp;
319     }
320 }
321

```

```

322     return minValue;
323 }
324
325 void PrintPath(int *pm, int width, int height, int index)
326 {
327     int i;
328     for (i=width-1; i>=0; --i) {
329         printf("%d ", index);
330         index = *(pm + index*width + i);
331     }
332     printf("\n");
333 }
334
335 void PrintMatrix(float *m, int width, int height)
336 {
337     int i;
338     int j;
339     for (i=0; i<height; ++i) {
340         printf("%d: ", i);
341         for (j=0; j<width; ++j)
342             printf("%6.2e ", *m++);
343         printf("\n");
344     }
345 }
346
347 typedef struct CTuple {
348     int index;
349     float value;
350 } CompareTuple;
351
352 int TupleLessThan(CompareTuple *t1, CompareTuple *t2)
353 {
354     return t1->value > t2->value;
355 }
356
357 void L2CompareDictToString(char *string,
358                           CorrelationSet *charCorrelations,
359                           CorrelationSet *blankCorrelations,
360                           Dictionary signalDict,
361                           Dictionary modelDict,
362                           BOOLEAN isBatch)
363 {
364     CompareTuple *results;
365     int i;
366
367     if ((results = (CompareTuple *)calloc(signalDict->numberOfEntries,
368                                           sizeof(CompareTuple))) ==
369         NULL)
370         DoError("L2CompareDictToString: cannot allocate space.\n", NULL);
371
372     for (i=0; i<signalDict->numberOfEntries; ++i) {
373         (*(results+i)).index = i;
374         (*(results+i)).value = L2CompareWithString(i, string,
375                                                    *(charCorrelations+i),
376                                                    *(blankCorrelations+i),

```



```

377         signalDict,
378         modelDict);
379     }
380
381     qsort(results,
382           signalDict->numberOfEntries,
383           sizeof(CompareTuple),
384           TupleLessThan);
385
386     if (isBatch) {
387         printf("%d(%f)\n",(*results).index,(*results).value);
388     }
389     else {
390         printf("\n");
391         for (i=0;(i<5)&&(i<signalDict->numberOfEntries); ++i)
392             printf("%d: %f\n",(*{results+i}).index,(*{results+i}).value);
393         printf("\n");
394     }
395
396     free(results);
397 }
398
399 void PrintDictStats(Dictionary dict)
400 {
401     int i,sum=0;
402     printf("Dictionary has %d entries.\n",dict->numberOfEntries);
403     for (i=0;i<dict->numberOfEntries; ++i)
404         sum += (*{dict->outlines+i})->numberOfLegs;
405     printf("The total length of the shape contours is %d pixels.\n",sum);
406 }
407
408 void main(int argc,char **argv)
409 {
410     char *unknowns,*models;
411     char s[MAX_STRING_LENGTH+1];
412     Dictionary unknownDict, modelDict;
413     int selection;
414     char *crPointer;
415     BOOLEAN done = FALSE;
416     BOOLEAN batch;
417     char *words;
418     CorrelationSet *charCorrelations;
419     CorrelationSet *blankCorrelations;
420
421     if (argc != 3 && argc != 4) {
422         printf("Usage:\n");
423         printf(" %s <unknowns> <alphabet> [<batch wordlist>]\n",argv[0]);
424         printf(" If the batch file is not specified, the program runs\n");
425         printf(" in interactive mode.\n");
426         exit(-1);
427     }
428
429     unknowns = argv[1];
430     models = argv[2];
431     if (argc == 4) {

```

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```

432     batch = TRUE;
433     words = argv[3];
434 } else
435     batch = FALSE;
436
437     unknownDict = ReadDictionary(unknowns);
438     modelDict = ReadDictionary(models);
439
440     PrintDictStats(unknownDict);
441     printf("Preprocessing ... \n");
442     charCorrelations = PreProcessDictionaryWithChars(unknownDict,modelDict);
443     blankCorrelations = PreProcessDictionaryWithBlanks(unknownDict);
444     printf("done.\n");
445
446     if (batch) {
447         FILE *fp;
448         if ((fp = fopen(words,"r")) == NULL)
449             DoError("l2Norm: can't open input file %s.\n",words);
450         while (!done) {
451             fgets(s,MAX_STRING_LENGTH,fp);
452             if ((s[0] == '\0') || (s[0] == '\n'))
453                 done = TRUE;
454             else {
455                 crPointer = strchr(s,'\n');
456                 if (crPointer != NULL)
457                     *crPointer = '\0';
458                 printf("%s: ",s);
459
460                 L2CompareDictToString(s,charCorrelations,blankCorrelations,unknownDict,modelDict,TRUE);
461             }
462         }
463     } else {
464         while (!done) {
465             printf("Enter a word to search for: ");
466             fgets(s,MAX_STRING_LENGTH,stdin);
467             if ((s[0] == '\0') || (s[0] == '\n'))
468                 done = TRUE;
469             else {
470                 crPointer = strchr(s,'\n');
471                 if (crPointer != NULL)
472                     *crPointer = '\0';
473                 printf("Comparing shape %s to the image\n",s);
474
475                 L2CompareDictToString(s,charCorrelations,blankCorrelations,unknownDict,modelDict,FALSE);
476             }
477         }
478     }
479

```

Jan 15 21:32 1991 match.c

```

1  /*
2  * match.c
3  * align 2 sequences
4  *
5  * run as: match seq1 seq2
6  *
7  */
8
9  /*
10 * TO DO: 1) don't compute over parts of array outside of constraints
11 *        2) distance score for top and bottom paths
12 */
13
14 #include <stdio.h>
15 #include <math.h>
16
17 #include "boolean.h"
18 #include "types.h"
19 #include "error.h"
20 #include "pict.h"
21 #include "dict.h"
22 #include "diff.h"
23 #include "diff2.h"
24 #include "match.h"
25
26 #ifndef MAXLINE
27 #define MAXLINE 256
28 #endif
29
30 #ifndef MAXNAME
31 #define MAXNAME 128
32 #endif
33
34 #ifndef TRUE
35 #define TRUE 1
36 #endif
37
38 #ifndef FALSE
39 #define FALSE 0
40 #endif
41
42 int matchcntr = 1; /* used for writing out set number of matches */
43
44 /*
45 void
46 main(argc,argv)
47 int argc;
48 char *argv[];
49 {
50 */
51 /*
52 * read in multiple parameter files, write out selected fields as shorts

```

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```

53     */
54     /*
55     int i,j;
56     int seqlength;
57     float matchvecs();
58
59     float test[MAXSEQLENGTH];
60     float ref[MAXSEQLENGTH];
61     */
62     /*
63     * read in args
64     */
65     /*
66     debug = FALSE;
67
68     for (;argc > 1 && (argv[1][0] == '-'); argc--, argv++)
69     {
70         switch (argv[1][1])
71         {
72             case 'd':
73                 debug = TRUE;
74                 break;
75             case 'h':
76                 horweight = (float)atoi(&argv[1][2]);
77                 break;
78             case 'v':
79                 verweight = (float)atoi(&argv[1][2]);
80                 break;
81             case 'x':
82                 diagweight = (float)atoi(&argv[1][2]);
83                 break;
84             default:
85                 printf ("match: unknown switch %s.\n", argv[1]);
86                 exit (1);
87         }
88     }
89
90     if (argc != 1)
91     {
92         printf ("Usage: match [-b <begsamp> -d(debug) -e <endsamp> \n");
93         printf ("argc: %d\n", argc);
94         exit (1);
95     }
96     */
97     /* debugging */
98     /* for (i = 0; i < 5; i++)
99         test[i] = (float)i;
100     for (i = 5; i < 10; i++)
101         test[i] = (float)(.5 * (i - 4) + 5);
102     for (i = 0; i < 5; i++)
103         ref[i] = 1.5 * i;
104     matchvecs(test, 10, ref, 5);
105
106     }
107     */

```

```

108
109  /*
110 float DPDiffPair(OutlinePair one, OutlinePair two)
111 {
112     if (one == two){
113         printf("matches\n");
114         return(0.0);
115     }
116     else {
117         printf("no match\n");
118         return(1.0);
119     }
120 }
121 */
122
123 float DPDiffPair(OutlinePair one, OutlinePair two)
124 /*
125  * question, should top and bottom distance be forced to be computed together?
126  * use another distance score to check how far off the two are?
127  */
128
129 {
130     float topscore;
131     float bottomscode;
132
133     if (debug) printf("top: ");
134     topscore = matchvecs(one->top, one->numberOfLegs,
135                          two->top, two->numberOfLegs);
136     if (debug) printf(" bottom: ");
137     bottomscode = matchvecs(one->bottom, one->numberOfLegs,
138                            two->bottom, two->numberOfLegs);
139     return (topscore + bottomscode);
140 }
141
142 float matchvecs(float *Vec1, int lenVec1, float *Vec2, int lenVec2)
143 /*
144  * Computes the best path between one and two.
145  * Allows 2/1 expansion/compression
146  */
147 {
148     float dist, mindist, hor, vert, diag;
149     float bestscore;
150     int i1, i2;
151     int xdir, ydir;
152
153     elt *array[MAXSELENGTH][MAXSELENGTH];
154     elt *aelt;
155
156     /* initialize array */
157
158     for (i1 = 0; i1 < lenVec1; i1++) {
159         for (i2 = 0; i2 < lenVec2; i2++) {
160             array[i1][i2] = (elt *) malloc(sizeof(elt));
161             if (array[i1][i2] == NULL) {
162                 fprintf(stderr,

```

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```

163         "Sorry, not enough space to malloc array elts in pl_matchvecs\n BYE!";
164     exit(1);
165 }
166 }
167 }
168
169 /*
170  * compute match
171  */
172 /* initialize */
173 aelt = array[0][0];
174 aelt->cost = sq_distance(Vec1[0], Vec2[0]);
175 aelt->xptr = 0;
176 aelt->yptr = 0;
177 /* bottom row */
178 i2 = 0;
179 for (i1 = 1; i1 < lenVec1; i1++) {
180     dist = sq_distance(Vec1[i1], Vec2[i2]);
181     aelt = array[i1][i2];
182     aelt->cost = array[i1 - 1][i2]->cost + horweight * dist;
183     aelt->xptr = -1;
184     aelt->yptr = 0;
185 }
186 /* left column */
187 i1 = 0;
188 for (i2 = 1; i2 < lenVec2; i2++) {
189     dist = sq_distance(Vec1[i1], Vec2[i2]);
190     aelt = array[i1][i2];
191     aelt->cost = array[i1][i2 - 1]->cost + verweight * dist;
192     aelt->xptr = 0;
193     aelt->yptr = -1;
194 }
195 /* middle */
196 for (i1 = 1; i1 < lenVec1; i1++) {
197     for (i2 = 1; i2 < lenVec2; i2++) {
198         dist = sq_distance(Vec1[i1], Vec2[i2]);
199         hor = array[i1 - 1][i2]->cost + horweight * dist;
200         xdir = -1;
201         ydir = 0;
202         mindist = hor;
203         vert = array[i1][i2 - 1]->cost + verweight * dist;
204         if (vert < mindist) {
205             xdir = 0;
206             ydir = -1;
207             mindist = vert;
208         }
209         diag = array[i1 - 1][i2 - 1]->cost + diagweight * dist;
210         if (diag < mindist) {
211             xdir = -1;
212             ydir = -1;
213             mindist = diag;
214         }
215         aelt = array[i1][i2];
216         aelt->cost = mindist;
217         aelt->xptr = xdir;

```

```

218     aelt->yptr = ydir;
219     }
220 }
221
222     bestscore = best_score(array, lenVec1, lenVec2);
223 #ifdef foo
224     if (debug) {
225         print_best_path(array, lenVec1, lenVec2);
226         /* print_array_costs(array, lenVec1, lenVec2);
227         print_array_dirs(array, lenVec1, lenVec2);
228         */
229         printf("best score: %f\n", bestscore);
230     }
231 #endif
232
233     for (i1 = 0; i1 < lenVec1; i1++) {
234         for (i2 = 0; i2 < lenVec2; i2++) {
235             free(array[i1][i2]);
236         }
237     }
238
239     return(bestscore);
240 }
241
242 float
243 sq_distance(float x1, float x2)
244 {
245     float dist;
246     float epsilon = .001;
247
248     /*
249     * quantization makes many values identical, use of epsilon encourages shortest path
250     */
251
252     dist = x1 - x2;
253     dist *= dist;
254     dist += epsilon;
255     return(dist);
256 }
257
258 /*
259 float parallel_distance(OutlinePair one, OutlinePair two, int ptr1, int ptr2)
260 {
261     float topdist, bottomdist;
262
263     topdist = one->top[ptr1] - two->top[ptr2];
264     topdist *= topdist;
265
266     bottomdist = one->bottom[ptr1] - two->bottom[ptr2];
267     bottomdist *= bottomdist;
268
269     return(topdist + bottomdist);
270 }
271 */
272

```

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```

273 float
274 best_score(elt *array[][MAXSEQLENGTH], int lenVec1, int lenVec2)
275 {
276     /* assume all of Vec1 and Vec2 are used, so just take value at end */
277
278     return(array[lenVec1 - 1][lenVec2 - 1]->cost);
279 }
280
281 /*
282  * *****
283  * debugging functions
284  */
285 #ifdef foo
286 void
287 print_best_path(elt *array[][MAXSEQLENGTH], int lenVec1, int lenVec2)
288 {
289     char path[MAXNAME];
290     int x, y;
291     elt *aelt;
292     FILE *ofp;
293
294     x = lenVec1 - 1;
295     y = lenVec2 - 1;
296
297     sprintf(path, "/net/piglet/piglet/speech/fchen/pics/paths/p%d.txt", FileCountY);
298
299     ofp = fopen(path, "a");
300     if(ofp == NULL)
301         printf("Cannot open output file %s.\n", path);
302
303     /* fprintf(ofp, " %3s %3s %6s\n", "x", "y", "cost");
304     */
305     while (x > 0 || y > 0) {
306         aelt = array[x][y];
307         fprintf(ofp, " %3d %3d %6.2f\n", x, y, aelt->cost);
308         x += aelt->xptr;
309         y += aelt->yptr;
310     }
311     /* fprintf(ofp, "\nmatch %d\n\n", matchcntr++);
312     */
313     fprintf(ofp, "\nmatch %d %d\n\n", FileCountX, FileCountY);
314     fclose(ofp);
315 }
316 #endif
317 static float sqr(float x)
318 {
319     return x*x;
320 }
321
322 void print_best_path(elt *array[][MAXSEQLENGTH], int lenVec1, int lenVec2,
323                     char *outFileName)
324 {
325     int x, y;
326     elt *aelt;
327     FILE *outFile;

```


Section C

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```

328     float dist = 0;
329
330     x = lenVec1 - 1;
331     y = lenVec2 - 1;
332
333     if ((outFile = (FILE *)fopen(outFileName, "w")) == NULL)
334         DoError("single: Cannot open output file %s.\n", outFileName);
335
336     while (x > 0 || y > 0) {
337         aelt = array[x][y];
338         fprintf(outFile, " %3d %3d %6.2f\n", x, y, aelt->cost);
339         dist += sqrt(sqr(aelt->xptr) + sqr(aelt->yptr));
340         x += aelt->xptr;
341         y += aelt->yptr;
342     }
343     fclose(outFile);
344     printf("distance = %f\n", dist);
345 }
346
347
348 void
349 print_array_costs(elt *array[][MAXSEQLENGTH], int lenVec1, int lenVec2)
350 {
351
352     int x, y;
353
354     for (y = 0; y < lenVec2; y++) {
355         for (x = 0; x < lenVec1; x++) {
356             printf("%7.2f ", array[x][y]->cost);
357         }
358         printf("\n");
359     }
360 }
361
362 void
363 print_array_dirs(elt *array[][MAXSEQLENGTH], int lenVec1, int lenVec2)
364 {
365
366     int x, y;
367
368     for (y = 0; y < lenVec2; y++) {
369         for (x = 0; x < lenVec1; x++) {
370             printf("%2d:%2d ", array[x][y]->xptr, array[x][y]->yptr);
371         }
372         printf("\n");
373     }
374 }

```

Section C

Jul 7 14:28 1991 matchparallel.c

```

1      /*
2      * matchparallel.c
3      * align 2 sequences
4      *
5      * dependent on match.c
6      */
7
8      /*
9      * TO DO: 1) don't compute over parts of array outside of constraints
10     *
11     */
12
13     #include <stdio.h>
14     #include <math.h>
15     #include "boolean.h"
16     #include "types.h"
17     #include "error.h"
18     #include "pict.h"
19     #include "dict.h"
20     #include "diff.h"
21     #include "diff2.h"
22     #include "match.h"
23     #include "matchparallel.h"
24
25     #ifndef MAXLINE
26     #define MAXLINE 256
27     #endif
28
29     #ifndef MAXNAME
30     #define MAXNAME 128
31     #endif
32
33     #ifndef TRUE
34     #define TRUE 1
35     #endif
36
37     #ifndef FALSE
38     #define FALSE 0
39     #endif
40
41     #ifndef max
42     #define max(a,b) ((a) > (b) ? (a) : (b))
43     #endif
44
45     #ifndef min
46     #define min(a,b) ((a) < (b) ? (a) : (b))
47     #endif
48
49     /*
50     * *****
51     * parallel match with full search
52     * *****

```

```

53  */
54
55  float pl_DPDiffPair(OutlinePair one, OutlinePair two, char *pathFile)
56  /*
57   * question, should top and bottom distance be forced to be computed together?
58   * use another distance score to check how far off the two are?
59   */
60
61  {
62      float score;
63
64      score = pl_matchvecs(one->top, one->bottom, one->numberOfLegs,
65                          two->top, two->bottom, two->numberOfLegs,
66                          pathFile);
67      return (score);
68  }
69
70  float pl_matchvecs(float *Vec1t, float *Vec1b, int lenVec1,
71                    float *Vec2t, float *Vec2b, int lenVec2,
72                    char *pathFile)
73  /*
74   * Computes the best path between one and two.
75   * Allows 2/1 expansion/compression
76   */
77  {
78      float dist, mindist, hor, vert, diag;
79      float bestscore;
80      int i1, i2;
81      int xdir, ydir;
82
83      elt *array[MAXSEQLENGTH][MAXSEQLENGTH];
84      elt *aelt;
85
86      /* initialize array */
87
88      for (i1 = 0; i1 < lenVec1; i1++) {
89          for (i2 = 0; i2 < lenVec2; i2++) {
90              array[i1][i2] = (elt *) malloc(sizeof(elt));
91              if (array[i1][i2] == NULL) {
92                  fprintf(stderr,
93                      "Sorry, not enough space to malloc array elts in pl_matchvecs\n BYE!");
94                  exit(1);
95              }
96          }
97      }
98
99      /*
100     * compute match
101     */
102     /* initialize */
103     aelt = array[0][0];
104     aelt->cost = sq_distance(Vec1t[0], Vec2t[0]) + sq_distance(Vec1b[0], Vec2b[0]);
105     aelt->xptr = 0;
106     aelt->yptr = 0;
107     /* bottom row */

```

```

53  */
54
55  float pl_DPDiffPair(OutlinePair one, OutlinePair two, char *pathFile)
56  /*
57   * question, should top and bottom distance be forced to be computed together?
58   * use another distance score to check how far off the two are?
59   */
60
61  {
62      float score;
63
64      score = pl_matchvecs(one->top, one->bottom, one->numberOfLegs,
65                          two->top, two->bottom, two->numberOfLegs,
66                          pathFile);
67      return (score);
68  }
69
70  float pl_matchvecs(float *Vec1t, float *Vec1b, int lenVec1,
71                    float *Vec2t, float *Vec2b, int lenVec2,
72                    char *pathFile)
73  /*
74   * Computes the best path between one and two.
75   * Allows 2/1 expansion/compression
76   */
77  {
78      float dist, mindist, hor, vert, diag;
79      float bestscore;
80      int i1, i2;
81      int xdir, ydir;
82
83      elt *array[MAXSEQLENGTH][MAXSEQLENGTH];
84      elt *aelt;
85
86      /* initialize array */
87
88      for (i1 = 0; i1 < lenVec1; i1++) {
89          for (i2 = 0; i2 < lenVec2; i2++) {
90              array[i1][i2] = (elt *) malloc(sizeof(elt));
91              if (array[i1][i2] == NULL) {
92                  fprintf(stderr,
93                      "Sorry, not enough space to malloc array elts in pl_matchvecs\n BYE!");
94                  exit(1);
95              }
96          }
97      }
98
99      /*
100     * compute match
101     */
102     /* initialize */
103     aelt = array[0][0];
104     aelt->cost = sq_distance(Vec1t[0], Vec2t[0]) + sq_distance(Vec1b[0], Vec2b[0]);
105     aelt->xptr = 0;
106     aelt->yptr = 0;
107     /* bottom row */

```

```

108     i2 = 0;
109     for (i1 = 1; i1 < lenVec1; i1++) {
110         dist = sq_distance(Vec1t[i1], Vec2t[i2]) + sq_distance(Vec1b[i1], Vec2b[i2]);
111         aelt = array[i1][i2];
112         aelt->cost = array[i1 - 1][i2]->cost + horweight * dist;
113         aelt->xptr = -1;
114         aelt->yptr = 0;
115     }
116     /* left column */
117     i1 = 0;
118     for (i2 = 1; i2 < lenVec2; i2++) {
119         dist = sq_distance(Vec1t[i1], Vec2t[i2]) + sq_distance(Vec1b[i1], Vec2b[i2]);
120         aelt = array[i1][i2];
121         aelt->cost = array[i1][i2 - 1]->cost + verweight * dist;
122         aelt->xptr = 0;
123         aelt->yptr = -1;
124     }
125     /* middle */
126     for (i1 = 1; i1 < lenVec1; i1++) {
127         for (i2 = 1; i2 < lenVec2; i2++) {
128             dist = sq_distance(Vec1t[i1], Vec2t[i2]) + sq_distance(Vec1b[i1], Vec2b[i2]);
129             hor = array[i1 - 1][i2]->cost + horweight * dist;
130             xdir = -1;
131             ydir = 0;
132             mindist = hor;
133             vert = array[i1][i2 - 1]->cost + verweight * dist;
134             if (vert < mindist) {
135                 xdir = 0;
136                 ydir = -1;
137                 mindist = vert;
138             }
139             diag = array[i1 - 1][i2 - 1]->cost + diagweight * dist;
140             if (diag < mindist) {
141                 xdir = -1;
142                 ydir = -1;
143                 mindist = diag;
144             }
145             aelt = array[i1][i2];
146             aelt->cost = mindist;
147             aelt->xptr = xdir;
148             aelt->yptr = ydir;
149         }
150     }
151
152     bestscore = best_score(array, lenVec1, lenVec2);
153     if (pathFile)
154         print_best_path(array, lenVec1, lenVec2, pathFile);
155
156
157     for (i1 = 0; i1 < lenVec1; i1++) {
158         for (i2 = 0; i2 < lenVec2; i2++) {
159             free(array[i1][i2]);
160         }
161     }
162

```

```

163     return(bestscore);
164 }
165
166
167 /*
168  * *****
169  * faster parallel match
170  * not optimal because warp is limited to swath of width "bw"
171  * *****
172  */
173
174 float faster_pl_DPDiffPair(OutlinePair one, OutlinePair two, char *pathFile)
175 /*
176  * question, should top and bottom distance be forced to be computed together?
177  * use another distance score to check how far off the two are?
178  */
179
180 {
181     float score;
182
183     score = faster_pl_matchvecs(one->top, one->bottom, one->numberOfLegs,
184                                two->top, two->bottom, two->numberOfLegs,
185                                pathFile);
186     return (score);
187 }
188
189 float faster_pl_matchvecs(float *Vec1t, float *Vec1b, int lenVec1,
190                           float *Vec2t, float *Vec2b, int lenVec2,
191                           char *pathFile)
192 /*
193  * Computes the best path between one and two.
194  * Allows 2/1 expansion/compression only within a band
195  */
196 {
197     float dist, mindist, hor, vert, diag;
198     float bestscore;
199     float ratio;
200     int i1, i2;
201     int xdir, ydir;
202     int beg, end, center;
203     int b; /* pointer to border */
204     int border; /* width of border on right side of swath */
205
206     elt *array[MAXSEQLENGTH][MAXSEQLENGTH];
207     elt *aelt;
208
209     float infinity = 1.0e30;
210     int bw = 20;
211
212     ratio = (float)lenVec1 / (float)lenVec2;
213     border = (int) (ratio + .999999);
214     /* if (debug)
215         printf("ratio: %f\n", ratio);
216     */ /* initialize array */
217

```

```

218     for (i1 = 0; i1 < lenVec1; i1++) {
219         for (i2 = 0; i2 < lenVec2; i2++) {
220             array[i1][i2] = (elt *) malloc(sizeof(elt));
221             if (array[i1][i2] == NULL) {
222                 fprintf(stderr,
223                     "Sorry, not enough space to malloc array elts in pl_matchvecs\n BYE!");
224                 exit(1);
225             }
226         }
227     }
228
229     /*
230     * compute match
231     */
232     /* initialize */
233     aelt = array[0][0];
234     aelt->cost = sq_distance(Vec1t[0], Vec2t[0]) + sq_distance(Vec1b[0], Vec2b[0]);
235     aelt->xptr = 0;
236     aelt->yptr = 0;
237     /* bottom row */
238     i2 = 0;
239     end = bw + border + 1;
240     for (i1 = 1; i1 < end; i1++) {
241         dist = sq_distance(Vec1t[i1], Vec2t[i2]) + sq_distance(Vec1b[i1], Vec2b[i2]);
242         aelt = array[i1][i2];
243         aelt->cost = array[i1 - 1][i2]->cost + horweight * dist;
244         aelt->xptr = -1;
245         aelt->yptr = 0;
246     }
247     /*
248     * swath
249     *
250     * set the elt before beg and at end to infinity, then the compute distances normally
251     * for the row
252     */
253     for (i2 = 1; i2 < lenVec2; i2++) {
254         center = i2 * ratio;
255         beg = max(1, center - bw);
256         end = min(lenVec1, center + bw + 1);
257         /* if (debug)
258             printf("center: %d, beg: %d, end: %d\n", center, beg, end);
259         */
260         /* beg */
261         aelt = array[beg - 1][i2];
262         aelt->xptr = 0;
263         aelt->yptr = -1;
264         if (beg == 1) {
265             dist = sq_distance(Vec1t[0], Vec2t[i2]) + sq_distance(Vec1b[0], Vec2b[i2]);
266             aelt->cost = array[0][i2 - 1]->cost + verweight * dist;
267         }
268         else {
269             aelt->cost = infinity;
270         }
271         /* end */
272         /* if (end < lenVec1) {
273             */

```

```

273     for (b = end; b < min(end + border, lenVec1); b++) {
274         /* if (debug)
275             printf("b: %d ", b);
276         */ aelt = array[b][i2];
277         aelt->cost = infinity;
278         aelt->xptr = -1;
279         aelt->yptr = 0;
280     }
281     for (i1 = beg; i1 < end; i1++) {
282         dist = sq_distance(Vec1t[i1], Vec2t[i2]) + sq_distance(Vec1b[i1], Vec2b[i2]);
283         hor = array[i1 - 1][i2]->cost + horweight * dist;
284         xdir = -1;
285         ydir = 0;
286         mindist = hor;
287         vert = array[i1][i2 - 1]->cost + verweight * dist;
288         if (vert < mindist) {
289             xdir = 0;
290             ydir = -1;
291             mindist = vert;
292         }
293         diag = array[i1 - 1][i2 - 1]->cost + diagweight * dist;
294         if (diag < mindist) {
295             xdir = -1;
296             ydir = -1;
297             mindist = diag;
298         }
299         aelt = array[i1][i2];
300         aelt->cost = mindist;
301         aelt->xptr = xdir;
302         aelt->yptr = ydir;
303     }
304 }
305
306 bestscore = best_score(array, lenVec1, lenVec2);
307 if (pathFile)
308     print_best_path(array, lenVec1, lenVec2, pathFile);
309
310 for (i1 = 0; i1 < lenVec1; i1++) {
311     for (i2 = 0; i2 < lenVec2; i2++) {
312         free(array[i1][i2]);
313     }
314 }
315
316 return(bestscore);
317 }
318
319
320 /*
321  * *****
322  * fastest parallel match
323  * warp limited to swath bw, plus no backtracking
324  * *****
325  */
326
327 float simple_pl_DPDiffPair(OutlinePair one, OutlinePair two)

```


Section C

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```

328  /*
329  * question, should top and bottom distance be forced to be computed together?
330  * use another distance score to check how far off the two are?
331  */
332
333  {
334      float score;
335
336      score = simple_pl_matchvecs(one->top, one->bottom, one->numberOfLegs,
337                                two->top, two->bottom, two->numberOfLegs);
338      return (score);
339  }
340
341  void PrintArrayRow(float *array,int width)
342  {
343      int i;
344      for (i=0;i<width; ++i)
345          printf("%2.2f ",*array++);
346      printf("\n");
347  }
348
349  void PrintArray(float *array,int height,int width,int signalWidth)
350  {
351      int i;
352      for (i=0;i<height; ++i) {
353          printf("%d: ",i);
354          PrintArrayRow(array+i*width,signalWidth);
355      }
356  }
357
358  float simple_pl_matchvecs(float *Vec1t, float *Vec1b, int lenVec1, float *Vec2t, float
359  *Vec2b, int lenVec2)
360  /*
361  * Computes the best path between one and two within a band.
362  * Allows 2/1 expansion/compression only within a band.
363  */
364  {
365      float dist, mindist, hor, vert, diag;
366      float bestscore;
367      float ratio;
368      int i1, i2;
369      int xdir, ydir;
370      int beg, end, center;
371      int b; /* pointer to border */
372      int border; /* width of border on right side of swath */
373
374      float array[MAXSEQLENGTH][MAXSEQLENGTH];
375
376      float infinity = 1.0e30;
377      int bw = 20;
378
379      ratio = (float)lenVec1/ (float)lenVec2;
380      border = (int) (ratio + .999999);
381      /* if (debug)
382          printf("ratio: %f\n", ratio);

```

```

382  /* initialize array */
383
384
385  /*
386   * compute match
387   */
388  /* initialize */
389  array[0][0] = sq_distance(Vec1t[0], Vec2t[0]) + sq_distance(Vec1b[0], Vec2b[0]);
390
391  /* bottom row */
392  i2 = 0;
393  end = bw + border + 1;
394  for (i1 = 1; i1 < end; i1++) {
395      dist = sq_distance(Vec1t[i1], Vec2t[i2]) + sq_distance(Vec1b[i1], Vec2b[i2]);
396      array[i1][i2] = array[i1 - 1][i2] + horweight * dist;
397  }
398  /*
399   * swath
400   *
401   * set the elt before beg and at end to infinity, then the compute distances normally
402   * for the row
403   */
404  for (i2 = 1; i2 < lenVec2; i2++) {
405      center = i2 * ratio;
406      beg = max(1, center - bw);
407      end = min(lenVec1, center + bw + 1);
408      /* if (debug)
409       printf("center: %d, beg: %d, end: %d\n", center, beg, end);
410       */
411      /* beg */
412      if (beg == 1) {
413          dist = sq_distance(Vec1t[0], Vec2t[i2]) + sq_distance(Vec1b[0], Vec2b[i2]);
414          array[beg - 1][i2] = array[0][i2 - 1] + verweight * dist;
415      }
416      else {
417          array[beg - 1][i2] = infinity;
418      }
419      /* end */
420      for (b = end; b < min(end + border, lenVec1); b++) {
421          /* if (debug)
422           printf("b: %d ", b);
423           */
424          array[b][i2] = infinity;
425      }
426      for (i1 = beg; i1 < end; i1++) {
427          dist = sq_distance(Vec1t[i1], Vec2t[i2]) + sq_distance(Vec1b[i1], Vec2b[i2]);
428          hor = array[i1 - 1][i2] + horweight * dist;
429          mindist = hor;
430          vert = array[i1][i2 - 1] + verweight * dist;
431          if (vert < mindist) {
432              mindist = vert;
433          }
434          diag = array[i1 - 1][i2 - 1] + diagweight * dist;
435          if (diag < mindist) {
436              mindist = diag;
437          }
438      }
439  }

```

Section C

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```
437     array[i1][i2] = mindist;
438 }
439 }
440
441 bestscore = array[lenVec1 - 1][lenVec2 - 1];
442 if (debug) {
443     printf("best score: %f\n", bestscore);
444 }
445
446 return(bestscore);
447 }
```

Jul 24 17:16 1991 newL2.c

```

1  #include <stdio.h>
2  #include <math.h>
3  #include "boolean.h"
4  #include "types.h"
5  #include "error.h"
6  #include "dict.h"
7
8  #define NORMAL_LENGTH (100.0)
9  #define MAX_SLOPE (2.0)
10 #define BIG_NUM (10.0e20)
11
12 void ResampleOutlinePair(OutlinePair a, float newToOldFactor)
13 /* Resample an outline pair using linear interpolation. */
14 {
15     int newWidth, oldWidth, i;
16     int oldLeft, oldRight;
17     float oldCenter;
18     float *newX, *newTop, *newBottom;
19     float *xCursor, *topCursor, *bottomCursor;
20
21     oldWidth = a->numberOfLegs;
22     newWidth = irint(newToOldFactor*oldWidth);
23
24     newX = (float *)calloc(newWidth, sizeof(float));
25     newTop = (float *)calloc(newWidth, sizeof(float));
26     newBottom = (float *)calloc(newWidth, sizeof(float));
27     if ((newX == NULL) || (newTop == NULL) || (newBottom == NULL))
28         DoError("ResampleOutlinePair: cannot allocate space.\n", NULL);
29
30     xCursor = newX;
31     topCursor = newTop;
32     bottomCursor = newBottom;
33
34     for (i=0; i<newWidth; ++i) {
35         oldCenter = i/(float)newWidth*(float)oldWidth;
36         oldLeft = irint(floor(oldCenter));
37         oldRight = irint(ceil(oldCenter));
38         if (oldLeft == oldRight) {
39             *xCursor++ = *(a->x+oldLeft);
40             *topCursor++ = *(a->top+oldLeft);
41             *bottomCursor++ = *(a->bottom+oldLeft);
42         }
43         else {
44             float slope;
45             slope = *(a->x+oldRight)-*(a->x+oldLeft);
46             *xCursor++ = *(a->x+oldLeft) + (oldCenter-oldLeft)*slope;
47             slope = *(a->top+oldRight)-*(a->top+oldLeft);
48             *topCursor++ = *(a->top+oldLeft) + (oldCenter-oldLeft)*slope;
49             slope = *(a->bottom+oldRight)-*(a->bottom+oldLeft);
50             *bottomCursor++ = *(a->bottom+oldLeft) + (oldCenter-oldLeft)*slope;
51         }
52     }

```

Section C

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```

53
54     free(a->x);
55     free(a->top);
56     free(a->bottom);
57
58     a->x = newX;
59     a->top = newTop;
60     a->bottom = newBottom;
61     a->numberOfLegs = newWidth;
62 }
63
64 float L2Norm(OutlinePair signal, int startOffset,
65             OutlinePair model, float topToBottom)
66 {
67     float *top1, *top2, *bottom1, *bottom2;
68     int i, overlap;
69     float sum;
70     float temp;
71
72     if ((startOffset < 0) ||
73         (startOffset + model->numberOfLegs > signal->numberOfLegs))
74         DoError("L2Norm: the model must overlap the signal.\n", NULL);
75
76     top1 = signal->top + startOffset;
77     top2 = model->top;
78     bottom1 = signal->bottom + startOffset;
79     bottom2 = model->bottom;
80
81     overlap = signal->numberOfLegs - startOffset;
82     if (overlap > model->numberOfLegs)
83         overlap = model->numberOfLegs;
84
85     for (i=0, sum=0; i<overlap; ++i) {
86         temp = *top1++ - *top2++;
87         sum += temp * temp * topToBottom;
88         temp = *bottom1++ - *bottom2++;
89         sum += temp * temp;
90     }
91
92     return sum;
93 }
94
95 float L2Compare(OutlinePair o1, OutlinePair o2, float topToBottom)
96 {
97     float slope = (float)o1->width/(float)o2->width;
98     if ((slope > MAX_SLOPE) || (1/slope > MAX_SLOPE))
99         return BIG_NUM;
100     if (o1->numberOfLegs != NORMAL_LENGTH)
101         ResampleOutlinePair(o1, NORMAL_LENGTH/o1->numberOfLegs);
102     if (o2->numberOfLegs != NORMAL_LENGTH)
103         ResampleOutlinePair(o2, NORMAL_LENGTH/o2->numberOfLegs);
104     return L2Norm(o1, o2, topToBottom);
105 }
106

```

Aug 14 20:54 1991 newMatch.c

```

1  #include <stdio.h>
2  #include "mylib.h"
3  #include "misc.h"
4  #include "types.h"
5  #include "dict.h"
6  #include "newMatch.h"
7
8  #define MAX_SIGNAL_LENGTH (800)
9  #define MAX_SLOPE (2.0)
10 #define BIG_NUM (10e20)
11
12 typedef enum {NONE,LEFT,DOWN,DOWNLEFT,D1L1,D2L1,D1L2} Direction;
13
14 extern double sqrt(double);
15 extern double cos(double);
16 extern double atan(double);
17 extern int irint(double);
18
19 /* Assumes that a represents the model and b represents the unknown.
20  * Weights places where the model is lower than the unknown more than
21  * cases where the model is higher than the unknown. The idea here is
22  * that valleys can be filled in by bleeding together, but that noise
23  * can rarely make a contour be too tall for extended periods.
24  */
25 float hillToValley = 1.0;
26 inline float SquareDifference(float a,float b)
27 {
28     float temp = a-b;
29     if (temp<0)
30         return temp*temp;
31     else
32         return temp*temp*hillToValley*hillToValley;
33     /* return (a-b)*(a-b); */
34 }
35
36 inline float FMax(float a,float b)
37 {
38     if (a>b)
39         return a;
40     else
41         return b;
42 }
43
44 inline float FMin(float a,float b)
45 {
46     if (a<b)
47         return a;
48     else
49         return b;
50 }
51
52 inline int IMax(int a,int b)

```

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```

53     {
54         if (a>b)
55             return a;
56         else
57             return b;
58     }
59
60     inline int IMin(int a,int b)
61     {
62         if (a<b)
63             return a;
64         else
65             return b;
66     }
67
68     float NewMatch(float *a1,float *a2,int aLength,float *b1,float *b2,int bLength,
69                   float centerWeight,BOOLEAN lengthNormalize,int normalBandWidth,
70                   float topToBottom)
71     {
72         float costs0[MAX_SIGNAL_LENGTH + 1];
73         float costs1[MAX_SIGNAL_LENGTH + 1];
74         int i,j,start,end,bandWidth,shift;
75         int realStart,realEnd,center,oldEnd;
76         float slope,angle;
77         float *a1c,*a2c,*cd,*cl,*cdl,*dc;
78         float oldCost,b1v,b2v,returnVal;
79
80         if (aLength>MAX_SIGNAL_LENGTH||bLength>MAX_SIGNAL_LENGTH)
81             DoError("NewMatch: maximum signal length exceeded.\n",NULL);
82
83         slope = (float)aLength/(float)bLength;
84
85         if ((slope>MAX_SLOPE)||((1/slope)>MAX_SLOPE)) {
86             return BIG_NUM;
87         }
88         angle = atan(slope);
89         bandWidth = irint(normalBandWidth/cos(angle));
90         center = 0;
91         realStart = center-bandWidth/2;
92         realEnd = realStart+bandWidth;
93         end = FMin(realEnd,aLength);
94
95         a1c = a1; /* a1 cursor */
96         a2c = a2; /* a2 cursor */
97         b1v = *b1; /* b1 value */
98         b2v = *b2; /* b2 value */
99         dc = costs0;
100         *dc++ = BIG_NUM;
101         oldCost = *dc++ =
102         SquareDifference(*a1c++ ,b1v)*topToBottom+SquareDifference(*a2c++ ,b2v);
103         for (j=1;j<end;++j)
104             oldCost = *dc++ =
105             oldCost+SquareDifference(*a1c++ ,b1v)*topToBottom+SquareDifference(*a2c++ ,b2v);

```

```

106     for (i=1;i<bLength; ++i) {
107         /* Compute new center of band */
108         center = irlint(slope*i);
109         realStart = center-bandWidth/2;
110         realEnd = realStart+bandWidth;
111         start = FMax(realStart,0);
112         oldEnd = end;
113         end = FMin(realEnd,aLength);
114         shift = end-oldEnd;
115
116         /* put large numbers where bands don't overlap */
117         for (j=0;j<shift; ++j)
118             *dc++ = BIG_NUM;
119
120         a1c = a1+start; /* a1 cursor */
121         a2c = a2+start; /* a2 cursor */
122         b1v = *(b1+i); /* b1 value */
123         b2v = *(b2+i); /* b2 value */
124         if (i&1) {
125             cd = costs1+start-1+1; /* cursor down ??? What about -1??? */
126             cdl = costs0+start-1+1; /* cursor down left */
127             cl = costs0+start+1; /* cursor left */
128             dc = costs1+start+1; /* destination cursor */
129         }
130         else {
131             cd = costs0+start-1+1; /* cursor down */
132             cdl = costs1+start-1+1; /* cursor down left */
133             cl = costs1+start+1; /* cursor left */
134             dc = costs0+start+1; /* destination cursor */
135         }
136         *cd = BIG_NUM;
137         for (j=start;j<end; ++j) {
138             float down,left,downLeft,rest;
139             down = *cd++ + rest;
140             left = *cl++ + rest;
141             downLeft = *cdl++ + rest*centerWeight;
142             rest = SquareDifference(*a1c++ ,b1v)*topToBottom+
143                 SquareDifference(*a2c++ ,b2v);
144             *dc++ = FMin(FMin(down,left),downLeft);
145         }
146     }
147
148     i--;
149     if (i&1)
150         dc = costs1+aLength-1+1;
151     else
152         dc = costs0+aLength-1+1;
153     returnVal = *dc;
154
155     if (lengthNormalize)
156         return returnVal/sqrt(aLength*aLength+bLength*bLength);
157     else
158         return returnVal;
159 }
160

```



```

161
162 float SepMatch(float *a1,int aLength,float *b1,int bLength,
163             float centerWeight,BOOLEAN lengthNormalize,int normalBandWidth)
164 {
165     float costs0[MAX_SIGNAL_LENGTH+1];
166     float costs1[MAX_SIGNAL_LENGTH+1];
167     int i,j,start,end,bandWidth,shift;
168     int realStart,realEnd,center,oldEnd;
169     float slope,angle;
170     float *a1c,*cd,*cl,*cdl,*dc;
171     float oldCost,b1v,returnVal;
172
173     if (aLength>MAX_SIGNAL_LENGTH||bLength>MAX_SIGNAL_LENGTH)
174         DoError("NewMatch: maximum signal length exceeded.\n",NULL);
175
176     slope = (float)aLength/(float)bLength;
177
178     if ((slope>MAX_SLOPE)||((1/slope)>MAX_SLOPE)) {
179         return BIG_NUM;
180     }
181     angle = atan(slope);
182     bandWidth = irint(normalBandWidth/cos(angle));
183     center = 0;
184     realStart = center-bandWidth/2;
185     realEnd = realStart+bandWidth;
186     end = FMin(realEnd,aLength);
187
188     a1c = a1; /* a1 cursor */
189     b1v = *b1; /* b1 value */
190     dc = costs0;
191     *dc++ = BIG_NUM;
192     oldCost = *dc++ = SquareDifference(*a1c++,b1v);
193
194     for (j=1;j<end;++j)
195         oldCost = *dc++ = oldCost+SquareDifference(*a1c++,b1v);
196
197     for (i=1;i<bLength;++i) {
198         /* Compute new center of band */
199         center = irint(slope*i);
200         realStart = center-bandWidth/2;
201         realEnd = realStart+bandWidth;
202         start = FMax(realStart,0);
203         oldEnd = end;
204         end = FMin(realEnd,aLength);
205         shift = end-oldEnd;
206
207         /* put large numbers where bands don't overlap */
208         for (j=0;j<shift;++j)
209             *dc++ = BIG_NUM;
210
211         a1c = a1+start; /* a1 cursor */
212         b1v = *(b1+i); /* b1 value */
213         if (i&1) {
214             cd = costs1+start-1+1; /* cursor down ??? What about -1??? */
215             cdl = costs0+start-1+1; /* cursor down left */

```

```

216     cl = costs0 + start + 1; /* cursor left */
217     dc = costs1 + start + 1; /* destination cursor */
218 }
219 else {
220     cd = costs0 + start - 1 + 1; /* cursor down */
221     cdl = costs1 + start - 1 + 1; /* cursor down left */
222     cl = costs1 + start + 1; /* cursor left */
223     dc = costs0 + start + 1; /* destination cursor */
224 }
225 *cd = BIG_NUM;
226 for (j = start; j < end; ++j) {
227     float down, left, downLeft, rest;
228     down = *cd + + + rest;
229     left = *cl + + + rest;
230     downLeft = *cdl + + + rest * centerWeight;
231     rest = SquareDifference(*a1c + +, b1v);
232     *dc + + = FMin(FMin(down, left), downLeft);
233 }
234 }
235
236 i--;
237 if (i & 1)
238     dc = costs1 + aLength - 1 + 1;
239 else
240     dc = costs0 + aLength - 1 + 1;
241 returnVal = *dc;
242
243 if (lengthNormalize)
244     return returnVal / sqrt(aLength * aLength + bLength * bLength);
245 else
246     return returnVal;
247 }
248
249 #define WIDTH (800)
250 #define H_MARGIN (20)
251 #define V_MARGIN (40)
252 #define H_SPACING (20)
253 #define V_SPACING (100) /* Must be greater than 2*X_HEIGHT */
254 #define X_HEIGHT (17)
255 void DrawVLine(Picture pict, int x, int yt, int yb)
256 {
257     int i;
258     for (i = yt; i < yb; ++i)
259         WritePixel(pict, x, i, 1);
260 }
261
262 void DrawOutline(Picture pict, int numberOfLegs, float *tops, float *bottoms, int x, int y)
263 {
264     int i, top, bottom;
265     for (i = 0; i < numberOfLegs; ++i) {
266         top = irint(-(tops + i) * X_HEIGHT);
267         bottom = irint((bottoms + i) * X_HEIGHT + X_HEIGHT);
268         DrawVLine(pict, i + x, top + y, bottom + y);
269     }
270 }

```

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```

271
272 void PrintPath(float *a1,float *a2,int aLength,float *b1,float *b2,int bLength,
273               Direction path[MAX_SIGNAL_LENGTH][MAX_SIGNAL_LENGTH],int i,
274               float returnVal,
275               FILE *pathFP)
276 {
277     int x,y,j;
278     int length = 0;
279     int index = 0;
280     float newTop1[MAX_SIGNAL_LENGTH],newBottom1[MAX_SIGNAL_LENGTH];
281     float newTop2[MAX_SIGNAL_LENGTH],newBottom2[MAX_SIGNAL_LENGTH];
282
283     y = i;
284     x = aLength-1;
285     while (path[y][x]!=NONE) {
286         switch (path[y][x]) {
287             case DOWN:
288                 x--;
289                 break;
290             case LEFT:
291                 y--;
292                 break;
293             case D1L1:
294             case DOWNLEFT:
295                 x--;
296                 y--;
297                 break;
298             case D2L1:
299                 x-=2;
300                 y--;
301                 break;
302             case D1L2:
303                 x--;
304                 y-=2;
305                 break;
306             default:
307                 DoError("NewMatchAndPath: Internal error - bad case.\n",NULL);
308         }
309         ++length;
310     }
311
312     y = i;
313     x = aLength-1;
314     while (path[y][x]!=NONE) {
315         if (index>=MAX_SIGNAL_LENGTH)
316             DoError("NewMatchAddPath: warped signal is too long.\n",NULL);
317         newTop1[length-index] = a1[x];
318         newBottom1[length-index] = a2[x];
319         newTop2[length-index] = b1[y];
320         newBottom2[length-index] = b2[y];
321         switch (path[y][x]) {
322             case DOWN:
323                 x--;
324                 break;
325             case LEFT:

```

```

326     y--;
327     break;
328     case D1L1:
329     case DOWNLEFT:
330     x--;
331     y--;
332     break;
333     case D2L1:
334     x=2;
335     y--;
336     break;
337     case D1L2:
338     x--;
339     y=2;
340     break;
341     default:
342     DoError("NewMatchAndPath: Internal error - bad case.\n",NULL);
343     }
344     ++ index;
345 }
346 if (index >= MAX_SIGNAL_LENGTH)
347     DoError("NewMatchAddPath: warped signal is too long.\n",NULL);
348 newTop1[length-index] = a1[x];
349 newBottom1[length-index] = a2[x];
350 newTop2[length-index] = b1[y];
351 newBottom2[length-index] = b2[y];
352 ++ index;
353
354 for (j=0; j<index; ++j)
355     fprintf(pathFP,"%d %f\n",j,newTop1[j]);
356 fprintf(pathFP,"\ntop1\n\n");
357
358 for (j=0; j<index; ++j)
359     fprintf(pathFP,"%d %f\n",j,newTop2[j]);
360 fprintf(pathFP,"\ntop2\n\n");
361
362 for (j=0; j<index; ++j)
363     fprintf(pathFP,"%d %f\n",j,-newBottom1[j]);
364 fprintf(pathFP,"\nbottom1\n\n");
365
366 for (j=0; j<index; ++j)
367     fprintf(pathFP,"%d %f\n",j,-newBottom2[j]);
368 fprintf(pathFP,"\nbottom2\n\n");
369
370 {
371     Picture pict;
372     pict =
new_pict(IMax(index,IMax(aLength,bLength))*2+H_SPACING+H_MARGIN*2,V_MARGIN*
2+2*V_SPACING,1);
373     DrawOutline(pict,aLength,a1,a2,H_MARGIN,V_MARGIN);
374     DrawOutline(pict,bLength,b1,b2,H_MARGIN+aLength+H_SPACING,V_MARGIN);
375
376     DrawOutline(pict,index,newTop1,newBottom1,H_MARGIN,V_MARGIN+V_SPACING);

```

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```

377 DrawOutline(pict,index,newTop2,newBottom2,H_MARGIN+index+H_SPACING,V_MARGI
N+V_SPACING);
378 DrawOutline(pict,index,newTop2,newBottom2,H_MARGIN,V_MARGIN+V_SPACING*2);
379 write_pict("out.pict",pict);
380 }
381
382 {
383     float checksum;
384     fprintf(pathFP,"%d %f\n",0,checksum);
385     for (j=0,checksum=0;j<index;++j) {
386         checksum += SquareDifference(newTop1[j],newTop2[j]) +
387             SquareDifference(newBottom1[j],newBottom2[j]);
388         fprintf(pathFP,"%d %f\n",j,checksum);
389     }
390     printf("checksum, score = %6.2f, %6.2f\n",checksum,returnVal);
391 }
392 }
393
394
395
396 float NewMatchAndPath(float *a1,float *a2,int aLength,float *b1,float *b2,int bLength,
397     float centerWeight,BOOLEAN lengthNormalize,int normalBandWidth,
398     float topToBottom,FILE *pathFP)
399 {
400     Direction path[MAX_SIGNAL_LENGTH][MAX_SIGNAL_LENGTH],*pc;
401     int x,y;
402     float costs0[MAX_SIGNAL_LENGTH+1];
403     float costs1[MAX_SIGNAL_LENGTH+1];
404     int i,j,start,end,bandWidth,shift;
405     int realStart,realEnd,center,oldEnd;
406     float slope,angle;
407     float *a1c,*a2c,*cd,*cl,*cdl,*dc;
408     float oldCost,b1v,b2v,returnVal;
409
410     if (aLength>MAX_SIGNAL_LENGTH||bLength>MAX_SIGNAL_LENGTH)
411         DoError("NewMatch: maximum signal length exceeded.\n",NULL);
412
413     slope = (float)aLength/(float)bLength;
414
415     if ((slope>MAX_SLOPE)||((1/slope)>MAX_SLOPE)) {
416         return BIG_NUM;
417     }
418     angle = atan(slope);
419     bandwidth = irint(normalBandWidth/cos(angle));
420     center = 0;
421     realStart = center-bandWidth/2;
422     realEnd = realStart+bandWidth;
423     end = FMin(realEnd,aLength);
424
425     a1c = a1; /* a1 cursor */
426     a2c = a2; /* a2 cursor */
427     b1v = *b1; /* b1 value */
428     b2v = *b2; /* b2 value */

```

```

429     dc = costs0;
430     pc = &(path[0][0]);
431     *dc++ = BIG_NUM;
432     oldCost = *dc++ =
SquareDifference(*a1c++ ,b1v)*topToBottom+SquareDifference(*a2c++ ,b2v);
433     *pc++ = NONE;
434
435     for (j=1;j<end;++j) {
436         oldCost = *dc++ =
oldCost+SquareDifference(*a1c++ ,b1v)*topToBottom+SquareDifference(*a2c++ ,b2v);
437         *pc++ = DOWN;
438     }
439
440     #ifdef foo
441     printf("%6d ",0);
442     for (j=0;j<end;++j)
443         printf("%6.2f ",costs0[j+1]);
444     #endif
445
446     for (i=1;i<bLength;++i) {
447         /* Compute new center of band */
448         center = irint(slope*i);
449         realStart = center-bandWidth/2;
450         realEnd = realStart+bandWidth;
451         start = FMax(realStart,0);
452         oldEnd = end;
453         end = FMin(realEnd,aLength);
454         shift = end-oldEnd;
455
456         /* put large numbers where bands don't overlap */
457         for (j=0;j<shift;++j) {
458             /* printf("%6.2f ",BIG_NUM); */
459             *dc++ = BIG_NUM;
460         }
461         /* printf("\n%6d ",i); */
462
463         a1c = a1+start; /* a1 cursor */
464         a2c = a2+start; /* a2 cursor */
465         b1v = *(b1+i); /* b1 value */
466         b2v = *(b2+i); /* b2 value */
467         pc = &(path[i](start));
468         if (i&1) {
469             cd = costs1+start-1+1; /* cursor down ??? What about -1??? */
470             cdl = costs0+start-1+1; /* cursor down left */
471             cl = costs0+start+1; /* cursor left */
472             dc = costs1+start+1; /* destination cursor */
473         }
474         else {
475             cd = costs0+start-1+1; /* cursor down */
476             cdl = costs1+start-1+1; /* cursor down left */
477             cl = costs1+start+1; /* cursor left */
478             dc = costs0+start+1; /* destination cursor */
479         }
480         *cd = BIG_NUM;
481         for (j=start;j<end;++j) {

```

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```

482     float down,left,downLeft,rest;
483     rest = SquareDifference(*a1c++ ,b1v)*topToBottom +
SquareDifference(*a2c++ ,b2v);
484     down = *cd++ + rest;
485     left = *cl++ + rest;
486     downLeft = *cdl++ + rest*centerWeight;
487
488     if (down < left)
489         if (down < downLeft) {
490             /*      printf("%6.2f ",down); */
491             *dc++ = down;
492             *pc++ = DOWN;
493         }
494         else {
495             /*      printf("%6.2f ",downLeft); */
496             *dc++ = downLeft;
497             *pc++ = DOWNLEFT;
498         }
499     else
500         if (downLeft < left) {
501             /*      printf("%6.2f ",downLeft); */
502             *dc++ = downLeft;
503             *pc++ = DOWNLEFT;
504         }
505         else {
506             /*      printf("%6.2f ",left); */
507             *dc++ = left;
508             *pc++ = LEFT;
509         }
510     }
511 }
512
513 i--;
514 if (i&1)
515     dc = costs1+aLength-1+1;
516 else
517     dc = costs0+aLength-1+1;
518 returnVal = *dc;
519
520 #ifdef foo
521 if (ldoPath) {
522     y = i;
523     x = aLength-1;
524     while (path[y][x] != NONE) {
525         switch (path[y][x]) {
526             case DOWN:
527                 x--;
528                 break;
529             case LEFT:
530                 y--;
531                 break;
532             case DOWNLEFT:
533                 x--;
534                 y--;
535                 break;

```

```

536     default:
537         DoError("NewMatchAndPath: Internal error - bad case.\n",NULL);
538     }
539     fprintf(pathFP,"%d %d\n",x,y);
540 }
541 fprintf(pathFP,"%d %d\n",x,y);
542 }
543 else {}
544 #endif
545 PrintPath(a1,a2,aLength,b1,b2,bLength,path,i,returnVal,pathFP);
546
547 if (lengthNormalize)
548     return returnVal/sqrt(aLength*aLength+bLength*bLength);
549 else
550     return returnVal;
551 }
552
553
554 float SlopeCMatch(float *a1,float *a2,int aLength,float *b1,float *b2,int bLength,
555                 float centerWeight,BOOLEAN lengthNormalize,float topToBottom)
556 {
557     float costs0[MAX_SIGNAL_LENGTH+2];
558     float costs1[MAX_SIGNAL_LENGTH+2];
559     float costs2[MAX_SIGNAL_LENGTH+2];
560     float slope,minVal;
561     int i,j;
562     int bottom,top;
563     float *cd1l1,*cd2l1,*cd1l2;
564     float *a1c,*a2c,*cd,*cl,*cdl,*dc;
565     float b1v,b2v,returnVal;
566
567     /* printf("sc:\n"); */
568
569     if (aLength>MAX_SIGNAL_LENGTH||bLength>MAX_SIGNAL_LENGTH)
570         DoError("SlopeCMatch: maximum signal length exceeded.\n",NULL);
571
572     slope = (float)aLength/(float)bLength;
573     if ((slope>MAX_SLOPE)||((1/slope)>MAX_SLOPE)) {
574         return BIG_NUM;
575     }
576
577     for (i=0;i<aLength+2;++i) {
578         costs2[i] = BIG_NUM;
579         costs1[i] = BIG_NUM;
580         costs0[i] = BIG_NUM;
581     }
582
583     costs0[2] = SquareDifference(*a1,*b1)*topToBottom+SquareDifference(*a2,*b2);
584
585     for (i=1;i<bLength;++i) {
586         bottom = IMax(i/2,2*i+aLength-2*bLength);
587         top = IMin(2*i,i/2+aLength-bLength/2)+1;
588
589         a1c = a1+bottom; /* a1 cursor */
590         a2c = a2+bottom; /* a2 cursor */

```


Section C

```

591     b1v = *(b1+i); /* b1 value */
592     b2v = *(b2+i); /* b2 value */
593
594     switch (i%3) {
595     case 0:
596         dc = costs0+bottom-2+2;
597         cd2l1 = costs2+bottom-2+2;
598         cd1l2 = costs1+bottom-1+2;
599         cd1l1 = costs2+bottom-1+2;
600         break;
601     case 1:
602         dc = costs1+bottom-2+2;
603         cd2l1 = costs0+bottom-2+2;
604         cd1l2 = costs2+bottom-1+2;
605         cd1l1 = costs0+bottom-1+2;
606         break;
607     case 2:
608         dc = costs2+bottom-2+2;
609         cd2l1 = costs1+bottom-2+2;
610         cd1l2 = costs0+bottom-1+2;
611         cd1l1 = costs1+bottom-1+2;
612         break;
613     }
614     *dc++ = BIG_NUM;
615     *dc++ = BIG_NUM;
616     for (j=bottom;j<top;++j) {
617         float d2l1,d1l2,d1l1,rest;
618         rest = SquareDifference(*a1c++ ,b1v)*topToBottom +
619             SquareDifference(*a2c++ ,b2v);
620         d1l1 = *cd1l1++ + rest*centerWeight;
621         d1l2 = *cd1l2++ + rest;
622         d2l1 = *cd2l1++ + rest;
623
624         *dc++ = FMin(FMin(d1l1,d2l1),d1l2);
625     }
626
627     switch (i%3) {
628     case 0:
629         dc = costs0;
630         break;
631     case 1:
632         dc = costs1;
633         break;
634     case 2:
635         dc = costs2;
636         break;
637     }
638
639     #ifdef foo
640     minVal = BIG_NUM;
641     printf("%6d: ",i);
642     for (j=0;j<aLength+2;++j) {
643         if (*dc <= minVal)
644             minVal = *dc;
645         if (*dc++ >= BIG_NUM)

```

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```

646         printf(" ");
647     else
648         printf(" *");
649     }
650     printf(" %6.2f\n",minVal);
651 #endif
652 }
653
654 --i;
655 switch (i%3) {
656 case 0:
657     dc = costs0;
658     break;
659 case 1:
660     dc = costs1;
661     break;
662 case 2:
663     dc = costs2;
664     break;
665 }
666 returnVal = *(dc+aLength-1+2);
667
668 if (lengthNormalize)
669     return returnVal/sqrt(aLength*aLength+bLength*bLength);
670 else
671     return returnVal;
672 }
673
674
675 float SepSlopeCMatch(float *a1,int aLength,float *b1,int bLength,
676                     float centerWeight,BOOLEAN lengthNormalize)
677 {
678     float costs0[MAX_SIGNAL_LENGTH+2];
679     float costs1[MAX_SIGNAL_LENGTH+2];
680     float costs2[MAX_SIGNAL_LENGTH+2];
681     float slope,minVal;
682     int i,j;
683     int bottom,top;
684     float *cd1l1,*cd2l1,*cd1l2;
685     float *a1c,*cd,*cl,*cdl,*dc;
686     float b1v,returnVal;
687
688     if (aLength>MAX_SIGNAL_LENGTH||bLength>MAX_SIGNAL_LENGTH)
689         DoError("SlopeCMatch: maximum signal length exceeded.\n",NULL);
690
691     slope = (float)aLength/(float)bLength;
692     if ((slope>MAX_SLOPE)||((1/slope)>MAX_SLOPE)) {
693         return BIG_NUM;
694     }
695
696     for (i=0;i<aLength+2; ++i) {
697         costs2[i] = BIG_NUM;
698         costs1[i] = BIG_NUM;
699         costs0[i] = BIG_NUM;
700     }

```

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```

701
702     costs0[2] = SquareDifference(*a1,*b1);
703
704     for (i=1;i<bLength; ++i) {
705         bottom = IMax(i/2,2*i+aLength-2*bLength);
706         top = IMin(2*i,i/2+aLength-bLength/2)+1;
707
708         a1c = a1+bottom; /* a1 cursor */
709         b1v = *(b1+i); /* b1 value */
710
711         switch (i%3) {
712             case 0:
713                 dc = costs0+bottom-2+2;
714                 cd2l1 = costs2+bottom-2+2;
715                 cd1l2 = costs1+bottom-1+2;
716                 cd1l1 = costs2+bottom-1+2;
717                 break;
718             case 1:
719                 dc = costs1+bottom-2+2;
720                 cd2l1 = costs0+bottom-2+2;
721                 cd1l2 = costs2+bottom-1+2;
722                 cd1l1 = costs0+bottom-1+2;
723                 break;
724             case 2:
725                 dc = costs2+bottom-2+2;
726                 cd2l1 = costs1+bottom-2+2;
727                 cd1l2 = costs0+bottom-1+2;
728                 cd1l1 = costs1+bottom-1+2;
729                 break;
730         }
731         *dc++ = BIG_NUM;
732         *dc++ = BIG_NUM;
733         for (j=bottom;j<top; ++j) {
734             float d2l1,d1l2,d1l1,rest;
735             rest = SquareDifference(*a1c++,b1v);
736             d1l1 = *cd1l1++ + rest*centerWeight;
737             d1l2 = *cd1l2++ + rest;
738             d2l1 = *cd2l1++ + rest;
739
740             *dc++ = FMin(FMin(d1l1,d2l1),d1l2);
741         }
742
743         switch (i%3) {
744             case 0:
745                 dc = costs0;
746                 break;
747             case 1:
748                 dc = costs1;
749                 break;
750             case 2:
751                 dc = costs2;
752                 break;
753         }
754     }
755

```

```

756     --i;
757     switch (i%3) {
758     case 0:
759         dc = costs0;
760         break;
761     case 1:
762         dc = costs1;
763         break;
764     case 2:
765         dc = costs2;
766         break;
767     }
768     returnVal = *(dc+aLength-1+2);
769
770     if (lengthNormalize)
771         return returnVal/sqrt(aLength*aLength+bLength*bLength);
772     else
773         return returnVal;
774 }
775
776 float SlopeCMatchAndPath(float *a1,float *a2,int aLength,float *b1,float *b2,int bLength,
777                         float centerWeight,BOOLEAN lengthNormalize,float topToBottom,
778                         FILE *pathFP)
779 {
780     Direction path[MAX_SIGNAL_LENGTH][MAX_SIGNAL_LENGTH],*pc;
781     float costs0[MAX_SIGNAL_LENGTH+2];
782     float costs1[MAX_SIGNAL_LENGTH+2];
783     float costs2[MAX_SIGNAL_LENGTH+2];
784     float slope,minVal;
785     int i,j;
786     int bottom,top;
787     float *cd1l1,*cd2l1,*cd1l2;
788     float *a1c,*a2c,*cd,*cl,*cdl,*dc;
789     float b1v,b2v,returnVal;
790
791     /* printf("sc:\n"); */
792
793     if (aLength>MAX_SIGNAL_LENGTH||bLength>MAX_SIGNAL_LENGTH)
794         DoError("SlopeCMatch: maximum signal length exceeded.\n",NULL);
795
796     slope = (float)aLength/(float)bLength;
797     if ((slope>MAX_SLOPE)||((1/slope)>MAX_SLOPE)) {
798         return BIG_NUM;
799     }
800
801     for (i=0;i<aLength+2; ++i) {
802         costs2[i] = BIG_NUM;
803         costs1[i] = BIG_NUM;
804         costs0[i] = BIG_NUM;
805     }
806
807     pc = &(path[0][0]);
808     *pc++ = NONE;
809     costs0[2] = SquareDifference(*a1,*b1)*topToBottom+SquareDifference(*a2,*b2);

```

```

811
812     for (i=1;i<bLength; ++i) {
813         bottom = IMax(i/2,2*i+aLength-2*bLength);
814         top = IMin(2*i,i/2+aLength-bLength/2)+1;
815
816         a1c = a1+bottom; /* a1 cursor */
817         a2c = a2+bottom; /* a2 cursor */
818         b1v = *(b1+i); /* b1 value */
819         b2v = *(b2+i); /* b2 value */
820
821         switch (i%3) {
822             case 0:
823                 dc = costs0+bottom-2+2;
824                 cd2l1 = costs2+bottom-2+2;
825                 cd1l2 = costs1+bottom-1+2;
826                 cd1l1 = costs2+bottom-1+2;
827                 break;
828             case 1:
829                 dc = costs1+bottom-2+2;
830                 cd2l1 = costs0+bottom-2+2;
831                 cd1l2 = costs2+bottom-1+2;
832                 cd1l1 = costs0+bottom-1+2;
833                 break;
834             case 2:
835                 dc = costs2+bottom-2+2;
836                 cd2l1 = costs1+bottom-2+2;
837                 cd1l2 = costs0+bottom-1+2;
838                 cd1l1 = costs1+bottom-1+2;
839                 break;
840         }
841         *dc++ = BIG_NUM;
842         *dc++ = BIG_NUM;
843         pc = &(path[i][bottom]);
844         for (j=bottom;j<top;++j) {
845             float d2l1,d1l2,d1l1,rest;
846
847             rest = SquareDifference(*a1c++,b1v)*topToBottom+
848                 SquareDifference(*a2c++,b2v);
849             d1l1 = *cd1l1++ + rest*centerWeight;
850             d1l2 = *cd1l2++ + rest;
851             d2l1 = *cd2l1++ + rest;
852
853             if (d1l1<d1l2)
854                 if (d1l1<d2l1) {
855                     *dc++ = d1l1;
856                     *pc++ = D1L1;
857                 }
858                 else {
859                     *dc++ = d2l1;
860                     *pc++ = D2L1;
861                 }
862             else
863                 if (d1l2<d2l1) {
864                     *dc++ = d1l2;
865                     *pc++ = D1L2;

```

```

866     }
867     else {
868         *dc++ = d2l1;
869         *pc++ = D2L1;
870     }
871 }
872
873 switch (i%3) {
874 case 0:
875     dc = costs0;
876     break;
877 case 1:
878     dc = costs1;
879     break;
880 case 2:
881     dc = costs2;
882     break;
883 }
884 minVal = BIG_NUM;
885 printf("%6d: ",i);
886 for (j=0;j<aLength+2;++j) {
887     if (*dc <= minVal)
888         minVal = *dc;
889     if (*dc++ >= BIG_NUM)
890         printf(" ");
891     else
892         printf("**");
893 }
894 printf("   %6.2f\n",minVal);
895 }
896
897 --i;
898 switch (i%3) {
899 case 0:
900     dc = costs0;
901     break;
902 case 1:
903     dc = costs1;
904     break;
905 case 2:
906     dc = costs2;
907     break;
908 }
909 returnVal = *(dc+aLength-1+2);
910
911 PrintPath(a1,a2,aLength,b1,b2,bLength,path,i,returnVal,pathFP);
912
913 if (lengthNormalize)
914     return returnVal/sqrt(aLength*aLength+bLength*bLength);
915 else
916     return returnVal;
917 }
918

```

Aug 202:29 1991 recogDesc.c

```

1  #include <stdio.h>
2  #include "mylib.h"
3  #include "types.h"
4  #include "dict.h"
5  #include "diff.h"
6
7  #define BIG_NUM (10e10)
8  #define MAX_WORDS (100)
9  #define MAX_FONTS (10)
10
11 extern double sqrt(double);
12
13 float CompareNumericDescriptors(float *a, float *b, int length)
14 {
15     int i;
16     float sum;
17     for (i=0; sum=0; i<length; ++i) {
18         sum += (*a-*b)*(*a-*b);
19         ++a;
20         ++b;
21     }
22     return sqrt(sum);
23 }
24
25 float *ComputeNumericDescriptor(int modelIndex, Dictionary models,
26                                Dictionary *fonts, int numberOfFonts, int numberOfWords,
27                                DiffDescriptor dd,
28                                float *sd, float *avg)
29 {
30     float *d;
31     int i, j;
32     float temp;
33     float sumxx[MAX_WORDS];
34     float sdev[MAX_WORDS];
35     float sumsdev, sumscore;
36
37     if ((d = (float *)calloc(numberOfWords, sizeof(float))) == NULL)
38         DoError("ComputeNumericDescriptor: cannot allocate space.\n", NULL);
39     for (j=0; j<numberOfWords; ++j)
40         sumxx[j] = 0;
41     for (i=0; i<numberOfFonts; ++i)
42         for (j=0; j<numberOfWords; ++j) {
43             temp = DiffPair(*(models->outlines + modelIndex), *(fonts[i]->outlines + j), dd);
44             if (temp < BIG_NUM) {
45                 d[j] += temp;
46                 sumxx[j] += temp*temp;
47             }
48         }
49
50     if (numberOfFonts > 1) {
51         float sum, minsdev, maxsdev;
52         for (j=0; j<numberOfWords; ++j)

```

```

53     sdev[j] = sqrt((numberOfFonts*sumxx[j]-d[j]*d[j])/numberOfFonts/(numberOfFonts-1));
54     for (j=0,sumsdev=0,sumscore=0;j<numberOfWords;++j) {
55         sumsdev += sdev[j];
56         sumscore += d[j];
57     }
58     *sd = sumsdev/numberOfWords;
59     *avg = sumscore/numberOfWords;
60 }
61
62 for (j=0;j<numberOfWords;++j)
63     d[j]/= numberOfFonts;
64
65 return d;
66 }
67
68 typedef struct {
69     float score;
70     int x;
71     int y;
72 } *CompareTuple, CompareTupleBody;
73
74 int TupleLessThan(CompareTuple *x, CompareTuple *y)
75 {
76     if ((*x)->score == (*y)->score)
77         return 0;
78     else if ((*x)->score < (*y)->score)
79         return -1;
80     else
81         return 1;
82 }
83
84
85 void DoDescriptors(Dictionary models, char *modelName, char **wordNames,
86                   int numberOfFonts, Dictionary *fonts, char **fontNames,
87                   int numberOfWords, DiffDescriptor dd)
88 {
89     float *descriptors[MAX_WORDS];
90     int classes[MAX_WORDS][MAX_WORDS];
91     float sdev[MAX_WORDS], avg[MAX_WORDS];
92     CompareTupleBody tuples[MAX_WORDS*MAX_WORDS];
93     CompareTuple scores[MAX_WORDS*MAX_WORDS];
94     int i, x, y, j;
95     int count;
96     /* float threshold = 0.22; */
97     float threshold = 0.42;
98
99     for (i=0; i<numberOfWords; ++i) {
100         descriptors[i] =
101             ComputeNumericDescriptor(i, models, fonts, numberOfFonts, numberOfWords, dd,
102                                     sdev+i, avg+i);
103         fprintf(stdout, "%s: %6.4f %6.4f\n", wordNames[i], avg[i], sdev[i]);
104     }
105     fprintf(stdout, "\n\n");
106     for (y=0; y<numberOfWords; ++y)

```



```

107     for (x=0;x<numberOfWords; ++x)
108         classes[y][x] =
109             (CompareNumericDescriptors(descriptors[y],descriptors[x],numberOfWords)
110              < threshold);
111
112     #ifdef foo
113     for (y=0,i=0;y<numberOfWords; ++y)
114         for (x=0;x<y; ++x) {
115             CompareTuple temp;
116             /*
117              temp = (CompareTuple)calloc(1,sizeof(CompareTupleBody));
118              if (temp == NULL)
119                  DoError(": cannot allocate space.\n",NULL);
120             */
121             temp = tuples + i;
122             temp->score =
123             CompareNumericDescriptors(descriptors[y],descriptors[x],numberOfWords);
124             temp->x = x;
125             temp->y = y;
126             scores[i] = temp;
127             ++i;
128         }
129         qsort(scores,i,sizeof(CompareTuple),TupleLessThan);
130         for (j=0;j<i; ++j)
131             fprintf(stdout,"%s,%s",
132                 wordNames[scores[j]->y],wordNames[scores[j]->x],scores[j]->score);
133         #endif
134         fprintf(stdout,"\n\n");
135         for (i=0;i<numberOfWords; ++i) {
136             CompareTuple temp;
137             float *thisDesc;
138             float junk;
139             thisDesc =
140             ComputeNumericDescriptor(i,models,&models,1,numberOfWords,dd,&junk,&junk);
141             for (j=0;j<numberOfWords; ++j) {
142                 temp = tuples + j;
143                 temp->score = CompareNumericDescriptors(thisDesc,descriptors[j],numberOfWords);
144                 temp->y = i;
145                 temp->x = j;
146                 scores[j] = temp;
147             }
148             qsort(scores,numberOfWords,sizeof(CompareTuple),TupleLessThan);
149             fprintf(stdout,"%s: ",wordNames[i]);
150             for (j=0;j<5&&j<numberOfWords; ++j) {
151                 fprintf(stdout,"%s ",wordNames[scores[j]->x]);
152                 if (scores[j]->x == i)
153                     break;
154             }
155             if (scores[j]->x == i)
156                 fprintf(stdout,"\n");
157             else {

```

```

158     for (;j<numberOfWords; ++j)
159         if (scores[j]>x==i)
160             break;
161     fprintf(stdout," (%d more)\n",j-5);
162 }
163
164 fprintf(stdout," ");
165 count = 0;
166 for (j=0;j<numberOfWords; ++j)
167     if (classes[scores[0]>x][j]) {
168         fprintf(stdout,"%s ",wordNames[j]);
169         ++count;
170         if (count > 5)
171             break;
172     }
173 if (j<numberOfWords) {
174     for (count=0;j<numberOfWords; ++j)
175         if (classes[scores[0]>x][j])
176             ++count;
177     fprintf(stdout," (% more)\n",count);
178 }
179 else
180     fprintf(stdout,"\n");
181
182 free(thisDesc);
183 }
184 }
185
186 void main(int argc,char **argv)
187 {
188     char *listFile;
189     Dictionary models;
190     char *modelName;
191     int numberOfFonts;
192     Dictionary fonts[MAX_FONTS];
193     char *fontNames[MAX_FONTS];
194     char *wordNames[MAX_WORDS];
195     int numberOfWords;
196     float centerWeight;
197     int normalBandWidth;
198     BOOLEAN
lengthNormalize,useL2,slopeConstrain,warp,topToBottomOption,hillToValleyOption;
199     BOOLEAN separate;
200     float topToBottom,hillToValleyLocal;
201     FILE *listfp;
202     int i,x,y;
203     DiffDescriptorBody dd;
204
205     centerWeight = 1.0;
206     normalBandWidth = 20;
207     topToBottom = 1.0;
208     hillToValleyLocal = 1.0;
209     DefArg("%s","listFile",&listFile);
210     DefOption("-L2","-L2",&useL2);
211     DefOption("-slopeConstrain %f","-slopeConstrain <center weight>",

```

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```

212         &slopeConstrain,&centerWeight);
213     DefOption("-warp %f %d","-warp <center weight> <band width> ",
214         &warp,&centerWeight,&normalBandWidth);
215     DefOption("-separate","-separate",&separate);
216     DefOption("-normalize","-normalize",&lengthNormalize);
217     DefOption("-topToBottom %f","-topToBottom
<ratio>",&topToBottomOption,&topToBottom);
218     DefOption("-hillToValley %f","-hillToValley
<ratio>",&hillToValleyOption,&hillToValleyLocal);
219     ScanArgs(argc,argv);
220
221     if ((listfp = fopen(listFile,"r")) == NULL)
222         DoError("Error opening file %s.\n",listFile);
223
224     /* Read in the number of words in each dictionary */
225     numberOfWords = ReadInt(listfp);
226     if (numberOfWords > MAX_WORDS)
227         DoError("%s: too many words.\n",argv[0]);
228
229     /* Read in the words */
230     for (i=0;i<numberOfWords; ++i) {
231         wordNames[i] = ReadString(listfp);
232     }
233
234     /* Read in the model dictionary */
235     modelName = ReadString(listfp);
236     models = ReadDictionary(modelName);
237
238     /* Read in the number of dictionaries */
239     numberOfFonts = ReadInt(listfp);
240     if (numberOfFonts > MAX_FONTS)
241         DoError("%s: too many dictionaries.\n",argv[0]);
242
243     /* Read in the dictionaries and their names */
244     for (i=0;i<numberOfFonts; ++i) {
245         fontNames[i] = ReadString(listfp);
246         fonts[i] = ReadDictionary(fontNames[i]);
247     }
248
249     /* Check to see that all dictionaries have the same number of shapes as the specified number
of words. */
250     for (i=1;i<numberOfFonts; ++i)
251         if (fonts[i]->numberOfEntries < numberOfWords)
252             DoError("Dictionary %s has too few entries.\n",fontNames[i]);
253     if (models->numberOfEntries < numberOfWords)
254         DoError("Model dictionary has too few of entries.\n",NULL);
255
256
257     if (useL2) {
258         fprintf(stdout,"Using L2 on length normalized shapes.\n");
259         dd.diffType = L2;
260     }
261     else if (slopeConstrain) {
262         fprintf(stdout,"Using dynamic time warping with slope constrained to [0.5,2].\n");
263         dd.diffType = CONSTRAINED;

```

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```

264     dd.separate = separate;
265     if (separate)
266         fprintf(stdout, "Top and bottom warped separately.\n");
267     else
268         fprintf(stdout, "Top and bottom warped together.\n");
269     }
270     else {
271         fprintf(stdout, "Using dynamic time warping with bandwidth %d.\n", normalBandWidth);
272         dd.diffType = WARP;
273         dd.bandWidth = normalBandWidth;
274         dd.separate = separate;
275         if (separate)
276             fprintf(stdout, "Top and bottom warped separately.\n");
277         else
278             fprintf(stdout, "Top and bottom warped together.\n");
279     }
280     if (!useL2) {
281         fprintf(stdout, "Center weight = %f.\n", centerWeight);
282         dd.centerWeight = centerWeight;
283         if (lengthNormalize) {
284             dd.lengthNormalize = TRUE;
285             fprintf(stdout, "Scores normalized by signal length.\n");
286         }
287         else
288             dd.lengthNormalize = FALSE;
289     }
290     dd.hillToValley = hillToValleyLocal;
291     dd.topToBottom = topToBottom;
292     dd.pathFP = NULL;
293
294     fprintf(stdout, "Words:\n");
295     for (i=0; i<numberOfWords; ++i)
296         fprintf(stdout, "%d: %s\n", i, wordNames[i]);
297     fprintf(stdout, "\n");
298     fprintf(stdout, "Model font is %s.\n", modelName);
299     fprintf(stdout, "Fonts:\n");
300     for (i=0; i<numberOfFonts; ++i)
301         fprintf(stdout, "%d: %s\n", i, fontNames[i]);
302     fprintf(stdout, "\n");
303
304     DoDescriptors(models, modelName, wordNames, numberOfFonts, fonts, fontNames, numberO
305     fWords, &dd);
306 }

```

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Jun 18 16:20 1991 resample.c

```

1    #include <stdio.h>
2    #include <values.h>
3    #include <string.h>
4    #include <floatingpoint.h>
5    #include "boolean.h"
6    #include "types.h"
7    #include "error.h"
8    #include "dict.h"
9
10   void Resample(OutlinePair signal,float factor)
11   {
12       int i,count;
13       float pivot;
14       float delFactor;
15       float *oldTop,*newTop;
16       float *oldBottom,*newBottom;
17       float *topSPtr,*topDPtr;
18       float *bottomSPtr,*bottomDPtr;
19
20       delFactor = 1.0 - factor;
21       for (i=0,count=0,pivot=0.0;i<signal->numberOfLegs; ++i) {
22           if (pivot>=1.0) {
23               pivot -= 1.0;
24               pivot += delFactor;
25           }
26           else {
27               pivot += delFactor;
28               ++count;
29           }
30       }
31
32       newTop = (float *)calloc(count,sizeof(float));
33       newBottom = (float *)calloc(count,sizeof(float));
34       if ((newTop==NULL)|| (newBottom==NULL))
35           DoError("Resample: cannot allocate space.\n",NULL);
36
37       oldTop = signal->top;
38       oldBottom = signal->bottom;
39
40       topSPtr = signal->top;
41       bottomSPtr = signal->bottom;
42       topDPtr = newTop;
43       bottomDPtr = newBottom;
44       for (i=0,pivot=0.0;i<signal->numberOfLegs; ++i) {
45           if (pivot>=1.0) {
46               pivot -= 1.0;
47               pivot += delFactor;
48               ++topSPtr;
49               ++bottomSPtr;
50           }
51           else {
52               pivot += delFactor;

```

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```

53     *topDPtr++ = *topSPtr++;
54     *bottomDPtr++ = *bottomSPtr++;
55 }
56 }
57
58 signal->top = newTop;
59 signal->bottom = newBottom;
60 signal->numberOfLegs = count;
61
62 free(oldTop);
63 free(oldBottom);
64 }
65
66 void main(int argc,char **argv)
67 {
68     char *inFile,*outFile;
69     float factor;
70     int i;
71     Dictionary dict;
72
73     if (argc != 4) {
74         fprintf(stderr,"Usage:\n");
75         fprintf(stderr," %s <input file> <output file> <compression factor>\n",argv[0]);
76         fprintf(stderr,"Compresses shapes horizontally.\n");
77         exit(-1);
78     }
79
80     if ((factor >= 1.0) || (factor < 0.0))
81         DoError("%s: factor must be between 0 and 1.\n",argv[0]);
82
83     inFile = argv[1];
84     outFile = argv[2];
85     factor = atof(argv[3]);
86
87     dict = ReadDictionary(inFile);
88
89     for (i=0;i<dict->numberOfEntries; ++i)
90         Resample(*(dict->outlines+i),factor);
91
92     WriteDictionary(dict,outFile);
93 }

```

Section C

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Jul 31 16:48 1991 sepMatch.c

```

1  #include <stdio.h>
2  #include "mylib.h"
3  #include "misc.h"
4
5  #define MAX_SIGNAL_LENGTH (800)
6  #define MAX_SLOPE (2.0)
7  #define BIG_NUM (10e20)
8
9  typedef enum {NONE,LEFT,DOWN,DOWNLEFT,D1L1,D2L1,D1L2} Direction;
10
11 extern double sqrt(double);
12 extern double cos(double);
13 extern double atan(double);
14 extern int irint(double);
15
16 /* Assumes that a represents the model and b represents the unknown.
17  * Weights places where the model is lower than the unknown more than
18  * cases where the model is higher than the unknown. The idea here is
19  * that valleys can be filled in by bleeding together, but that noise
20  * can rarely make a contour be too tall for extended periods.
21  */
22 float hillToValley = 1.0;
23 inline float SquareDifference(float a,float b)
24 {
25     float temp = a-b;
26     if (temp<0)
27         return temp*temp;
28     else
29         return temp*temp*hillToValley*hillToValley;
30     /* return (a-b)*(a-b); */
31 }
32
33 inline float FMax(float a,float b)
34 {
35     if (a>b)
36         return a;
37     else
38         return b;
39 }
40
41 inline float FMin(float a,float b)
42 {
43     if (a<b)
44         return a;
45     else
46         return b;
47 }
48
49 inline int IMax(int a,int b)
50 {
51     if (a>b)
52         return a;

```

```

53     else
54         return b;
55     }
56
57     inline int IMin(int a,int b)
58     {
59         if (a < b)
60             return a;
61         else
62             return b;
63     }
64
65     float NewMatch(float *a1,float *a2,int aLength,float *b1,float *b2,int bLength,
66                   float centerWeight,BOOLEAN lengthNormalize,int normalBandWidth,
67                   float topToBottom)
68     {
69         float costs0[MAX_SIGNAL_LENGTH + 1];
70         float costs1[MAX_SIGNAL_LENGTH + 1];
71         int i,j,start,end,bandWidth,shift;
72         int realStart,realEnd,center,oldEnd;
73         float slope,angle;
74         float *a1c,*a2c,*cd,*cl,*cdl,*dc;
75         float oldCost,b1v,b2v,returnVal;
76
77         if (aLength > MAX_SIGNAL_LENGTH || bLength > MAX_SIGNAL_LENGTH)
78             DoError("NewMatch: maximum signal length exceeded.\n",NULL);
79
80         slope = (float)aLength/(float)bLength;
81
82         if ((slope > MAX_SLOPE) || (1/slope > MAX_SLOPE)) {
83             return BIG_NUM;
84         }
85         angle = atan(slope);
86         bandWidth = irint(normalBandWidth/cos(angle));
87         center = 0;
88         realStart = center-bandWidth/2;
89         realEnd = realStart+bandWidth;
90         end = FMin(realEnd,aLength);
91
92         a1c = a1; /* a1 cursor */
93         a2c = a2; /* a2 cursor */
94         b1v = *b1; /* b1 value */
95         b2v = *b2; /* b2 value */
96         dc = costs0;
97         *dc++ = BIG_NUM;
98         oldCost = *dc++ =
99             SquareDifference(*a1c++ + b1v)*topToBottom + SquareDifference(*a2c++ + b2v);
100
101         for (j=1;j<end;++j)
102             oldCost = *dc++ =
103                 oldCost + SquareDifference(*a1c++ + b1v)*topToBottom + SquareDifference(*a2c++ + b2v);
104
105         for (i=1;i<bLength;++i) {
106             /* Compute new center of band */
107             center = irint(slope*i);

```



```

106     realStart = center-bandWidth/2;
107     realEnd = realStart + bandwidth;
108     start = FMax(realStart,0);
109     oldEnd = end;
110     end = FMin(realEnd,aLength);
111     shift = end-oldEnd;
112
113     /* put large numbers where bands don't overlap */
114     for (j=0;j<shift;++j)
115         *dc++ = BIG_NUM;
116
117     a1c = a1 + start; /* a1 cursor */
118     a2c = a2 + start; /* a2 cursor */
119     b1v = *(b1+i); /* b1 value */
120     b2v = *(b2+i); /* b2 value */
121     if (i&1) {
122         cd = costs1 + start - 1 + 1; /* cursor down ??? What about -1??? */
123         cdl = costs0 + start - 1 + 1; /* cursor down left */
124         cl = costs0 + start + 1; /* cursor left */
125         dc = costs1 + start + 1; /* destination cursor */
126     }
127     else {
128         cd = costs0 + start - 1 + 1; /* cursor down */
129         cdl = costs1 + start - 1 + 1; /* cursor down left */
130         cl = costs1 + start + 1; /* cursor left */
131         dc = costs0 + start + 1; /* destination cursor */
132     }
133     *cd = BIG_NUM;
134     for (j=start;j<end;++j) {
135         float down,left,downLeft,rest;
136         down = *cd++ + rest;
137         left = *cl++ + rest;
138         downLeft = *cdl++ + rest*centerWeight;
139         rest = SquareDifference(*a1c++ ,b1v)*topToBottom +
140             SquareDifference(*a2c++ ,b2v);
141         *dc++ = FMin(FMin(down,left),downLeft);
142     }
143 }
144
145 i--;
146 if (i&1)
147     dc = costs1 + aLength - 1 + 1;
148 else
149     dc = costs0 + aLength - 1 + 1;
150 returnVal = *dc;
151
152 if (lengthNormalize)
153     return returnVal/sqrt(aLength*aLength + bLength*bLength);
154 else
155     return returnVal;
156 }
157
158
159 void PrintPath(float *a1,float *a2,int aLength,float *b1,float *b2,int bLength,
160     Direction path[MAX_SIGNAL_LENGTH][MAX_SIGNAL_LENGTH],int i,

```

```

161         float returnVal,
162         FILE *pathFP)
163     {
164         int x,y,j;
165         int length = 0;
166         int index = 0;
167         float newTop1[MAX_SIGNAL_LENGTH],newBottom1[MAX_SIGNAL_LENGTH];
168         float newTop2[MAX_SIGNAL_LENGTH],newBottom2[MAX_SIGNAL_LENGTH];
169
170         y = i;
171         x = aLength-1;
172         while (path[y][x] != NONE) {
173             switch (path[y][x]) {
174                 case DOWN:
175                     x--;
176                     break;
177                 case LEFT:
178                     y--;
179                     break;
180                 case D1L1:
181                 case DOWNLEFT:
182                     x--;
183                     y--;
184                     break;
185                 case D2L1:
186                     x-=2;
187                     y--;
188                     break;
189                 case D1L2:
190                     x--;
191                     y-=2;
192                     break;
193                 default:
194                     DoError("NewMatchAndPath: Internal error - bad case.\n",NULL);
195             }
196             ++length;
197         }
198
199         y = i;
200         x = aLength-1;
201         while (path[y][x] != NONE) {
202             if (index >= MAX_SIGNAL_LENGTH)
203                 DoError("NewMatchAddPath: warped signal is too long.\n",NULL);
204             newTop1[length-index] = a1[x];
205             newBottom1[length-index] = a2[x];
206             newTop2[length-index] = b1[y];
207             newBottom2[length-index] = b2[y];
208             switch (path[y][x]) {
209                 case DOWN:
210                     x--;
211                     break;
212                 case LEFT:
213                     y--;
214                     break;
215                 case D1L1:

```

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```

216     case DOWNLEFT:
217         x--;
218         y--;
219         break;
220     case D2L1:
221         x-=2;
222         y--;
223         break;
224     case D1L2:
225         x--;
226         y-=2;
227         break;
228     default:
229         DoError("NewMatchAndPath: Internal error - bad case.\n",NULL);
230     }
231     ++ index;
232 }
233 if (index >= MAX_SIGNAL_LENGTH)
234     DoError("NewMatchAddPath: warped signal is too long.\n",NULL);
235 newTop1[length-index] = a1[x];
236 newBottom1[length-index] = a2[x];
237 newTop2[length-index] = b1[y];
238 newBottom2[length-index] = b2[y];
239 ++ index;
240
241 for (j=0;j<index; ++j)
242     fprintf(pathFP, "%d %f\n", j, newTop1[j]);
243 fprintf(pathFP, "\ntop1\n\n");
244
245 for (j=0;j<index; ++j)
246     fprintf(pathFP, "%d %f\n", j, newTop2[j]);
247 fprintf(pathFP, "\ntop2\n\n");
248
249 for (j=0;j<index; ++j)
250     fprintf(pathFP, "%d %f\n", j, -newBottom1[j]);
251 fprintf(pathFP, "\nbottom1\n\n");
252
253 for (j=0;j<index; ++j)
254     fprintf(pathFP, "%d %f\n", j, -newBottom2[j]);
255 fprintf(pathFP, "\nbottom2\n\n");
256
257 {
258     float checksum;
259     fprintf(pathFP, "%d %f\n", 0, checksum);
260     for (j=0;checksum=0;j<index; ++j) {
261         checksum += SquareDifference(newTop1[j], newTop2[j]) +
262             SquareDifference(newBottom1[j], newBottom2[j]);
263         fprintf(pathFP, "%d %f\n", j, checksum);
264     }
265     printf("checksum, score = %6.2f, %6.2f\n", checksum, returnVal);
266 }
267 }
268
269
270

```

```

271 float NewMatchAndPath(float *a1,float *a2,int aLength,float *b1,float *b2,int bLength,
272 float centerWeight,BOOLEAN lengthNormalize,int normalBandWidth,
273 float topToBottom,FILE *pathFP)
274 {
275     Direction path[MAX_SIGNAL_LENGTH][MAX_SIGNAL_LENGTH],*pc;
276     int x,y;
277     float costs0[MAX_SIGNAL_LENGTH+1];
278     float costs1[MAX_SIGNAL_LENGTH+1];
279     int i,j,start,end,bandWidth,shift;
280     int realStart,realEnd,center,oldEnd;
281     float slope,angle;
282     float *a1c,*a2c,*cd,*cl,*cdl,*dc;
283     float oldCost,b1v,b2v,returnVal;
284
285     if (aLength>MAX_SIGNAL_LENGTH||bLength>MAX_SIGNAL_LENGTH)
286         DoError("NewMatch: maximum signal length exceeded.\n",NULL);
287
288     slope = (float)aLength/(float)bLength;
289
290     if ((slope>MAX_SLOPE)||((1/slope)>MAX_SLOPE)) {
291         return BIG_NUM;
292     }
293     angle = atan(slope);
294     bandWidth = irint(normalBandWidth/cos(angle));
295     center = 0;
296     realStart = center-bandWidth/2;
297     realEnd = realStart+bandWidth;
298     end = FMin(realEnd,aLength);
299
300     a1c = a1; /* a1 cursor */
301     a2c = a2; /* a2 cursor */
302     b1v = *b1; /* b1 value */
303     b2v = *b2; /* b2 value */
304     dc = costs0;
305     pc = &(path[0][0]);
306     *dc++ = BIG_NUM;
307     oldCost = *dc++ =
308     SquareDifference(*a1c++,b1v)*topToBottom+SquareDifference(*a2c++,b2v);
309     *pc++ = NONE;
310
311     for (j=1;j<end;++j) {
312         oldCost = *dc++ =
313         oldCost+SquareDifference(*a1c++,b1v)*topToBottom+SquareDifference(*a2c++,b2v);
314         *pc++ = DOWN;
315     }
316
317     #ifdef foo
318     printf("%6d ",0);
319     for (j=0;j<end;++j)
320         printf("%6.2f ",costs0[j+1]);
321     #endif
322
323     for (i=1;i<bLength;++i) {
324         /* Compute new center of band */
325         center = irint(slope*i);

```

```

324     realStart = center-bandWidth/2;
325     realEnd = realStart + bandwidth;
326     start = FMax(realStart,0);
327     oldEnd = end;
328     end = FMin(realEnd,aLength);
329     shift = end-oldEnd;
330
331     /* put large numbers where bands don't overlap */
332     for (j=0;j<shift;++j) {
333     /*   printf("%6.2f ",BIG_NUM); */
334         *dc++ = BIG_NUM;
335     }
336     /*   printf("\n%6d ",i); */
337
338     a1c = a1+start; /* a1 cursor */
339     a2c = a2+start; /* a2 cursor */
340     b1v = *(b1+i); /* b1 value */
341     b2v = *(b2+i); /* b2 value */
342     pc = &(path[i][start]);
343     if (i&1) {
344         cd = costs1+start-1+1; /* cursor down ??? What about -1??? */
345         cdl = costs0+start-1+1; /* cursor down left */
346         cl = costs0+start+1; /* cursor left */
347         dc = costs1+start+1; /* destination cursor */
348     }
349     else {
350         cd = costs0+start-1+1; /* cursor down */
351         cdl = costs1+start-1+1; /* cursor down left */
352         cl = costs1+start+1; /* cursor left */
353         dc = costs0+start+1; /* destination cursor */
354     }
355     *cd = BIG_NUM;
356     for (j=start;j<end;++j) {
357         float down,left,downLeft,rest;
358         rest = SquareDifference(*a1c++,b1v)*topToBottom +
359             SquareDifference(*a2c++,b2v);
360         down = *cd++ + rest;
361         left = *cl++ + rest;
362         downLeft = *cdl++ + rest*centerWeight;
363         if (down < left)
364             if (down < downLeft) {
365             /*   printf("%6.2f ",down); */
366                 *dc++ = down;
367                 *pc++ = DOWN;
368             }
369             else {
370             /*   printf("%6.2f ",downLeft); */
371                 *dc++ = downLeft;
372                 *pc++ = DOWNLEFT;
373             }
374         else
375             if (downLeft < left) {
376             /*   printf("%6.2f ",downLeft); */
377                 *dc++ = downLeft;

```

```

378         *pc++ = DOWNLEFT;
379     }
380     else {
381         /* printf("%6.2f ",left); */
382         *dc++ = left;
383         *pc++ = LEFT;
384     }
385 }
386 }
387
388 i--;
389 if (i&1)
390     dc = costs1+aLength-1+1;
391 else
392     dc = costs0+aLength-1+1;
393 returnVal = *dc;
394
395 #ifdef foo
396 if (!doPath) {
397     y = i;
398     x = aLength-1;
399     while (path[y][x] != NONE) {
400         switch (path[y][x]) {
401             case DOWN:
402                 x--;
403                 break;
404             case LEFT:
405                 y--;
406                 break;
407             case DOWNLEFT:
408                 x--;
409                 y--;
410                 break;
411             default:
412                 DoError("NewMatchAndPath: Internal error - bad case.\n",NULL);
413         }
414         fprintf(pathFP,"%d %d\n",x,y);
415     }
416     fprintf(pathFP,"%d %d\n",x,y);
417 }
418 else {}
419 #endif
420 PrintPath(a1,a2,aLength,b1,b2,bLength,path,i,returnVal,pathFP);
421
422 if (lengthNormalize)
423     return returnVal/sqrt(aLength*aLength+bLength*bLength);
424 else
425     return returnVal;
426 }
427
428 float SlopeCMatch(float *a1,float *a2,int aLength,float *b1,float *b2,int bLength,
429                 float centerWeight,BOOLEAN lengthNormalize,float topToBottom)
430 {
431     float costs0[MAX_SIGNAL_LENGTH+2];
432

```

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```

433     float costs1[MAX_SIGNAL_LENGTH+2];
434     float costs2[MAX_SIGNAL_LENGTH+2];
435     float slope,minVal;
436     int i,j;
437     int bottom,top;
438     float *cd1l1,*cd2l1,*cd1l2;
439     float *a1c,*a2c,*cd,*cl,*cdl,*dc;
440     float b1v,b2v,returnVal;
441
442     /* printf("sc:\n"); */
443
444     if (aLength>MAX_SIGNAL_LENGTH||bLength>MAX_SIGNAL_LENGTH)
445         DoError("SlopeCMatch: maximum signal length exceeded.\n",NULL);
446
447     slope = (float)aLength/(float)bLength;
448     if ((slope>MAX_SLOPE)||((1/slope)>MAX_SLOPE)) {
449         return BIG_NUM;
450     }
451
452     for (i=0;i<aLength+2;++i) {
453         costs2[i] = BIG_NUM;
454         costs1[i] = BIG_NUM;
455         costs0[i] = BIG_NUM;
456     }
457
458     costs0[2] = SquareDifference(*a1,*b1)*topToBottom+SquareDifference(*a2,*b2);
459
460     for (i=1;i<bLength;++i) {
461         bottom = IMax(i/2,2*i+aLength-2*bLength);
462         top = IMin(2*i,i/2+aLength-bLength/2)+1;
463
464         a1c = a1+bottom; /* a1 cursor */
465         a2c = a2+bottom; /* a2 cursor */
466         b1v = *(b1+i); /* b1 value */
467         b2v = *(b2+i); /* b2 value */
468
469         switch (i%3) {
470             case 0:
471                 dc = costs0+bottom-2+2;
472                 cd2l1 = costs2+bottom-2+2;
473                 cd1l2 = costs1+bottom-1+2;
474                 cd1l1 = costs2+bottom-1+2;
475                 break;
476             case 1:
477                 dc = costs1+bottom-2+2;
478                 cd2l1 = costs0+bottom-2+2;
479                 cd1l2 = costs2+bottom-1+2;
480                 cd1l1 = costs0+bottom-1+2;
481                 break;
482             case 2:
483                 dc = costs2+bottom-2+2;
484                 cd2l1 = costs1+bottom-2+2;
485                 cd1l2 = costs0+bottom-1+2;
486                 cd1l1 = costs1+bottom-1+2;
487                 break;

```

```

488     }
489     *dc++ = BIG_NUM;
490     *dc++ = BIG_NUM;
491     for (j=bottom;j<top;++j) {
492         float d2l1,d1l2,d1l1,rest;
493         rest = SquareDifference(*a1c++,b1v)*topToBottom+
494             SquareDifference(*a2c++,b2v);
495         d1l1 = *cd1l1++ + rest*centerWeight;
496         d1l2 = *cd1l2++ + rest;
497         d2l1 = *cd2l1++ + rest;
498
499         *dc++ = FMin(FMin(d1l1,d2l1),d1l2);
500     }
501
502     switch (i%3) {
503     case 0:
504         dc = costs0;
505         break;
506     case 1:
507         dc = costs1;
508         break;
509     case 2:
510         dc = costs2;
511         break;
512     }
513
514     #ifdef foo
515     minVal = BIG_NUM;
516     printf("%6d: ",i);
517     for (j=0;j<aLength+2;++j) {
518         if (*dc <= minVal)
519             minVal = *dc;
520         if (*dc++ >= BIG_NUM)
521             printf(" ");
522         else
523             printf("*");
524     }
525     printf(" %6.2f\n",minVal);
526     #endif
527 }
528
529 --i;
530 switch (i%3) {
531 case 0:
532     dc = costs0;
533     break;
534 case 1:
535     dc = costs1;
536     break;
537 case 2:
538     dc = costs2;
539     break;
540 }
541 returnVal = *(dc+aLength-1+2);
542

```


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```

543     if (lengthNormalize)
544         return returnVal/sqrt(aLength*aLength+bLength*bLength);
545     else
546         return returnVal;
547 }
548
549
550 float SlopeCMatchAndPath(float *a1,float *a2,int aLength,float *b1,float *b2,int bLength,
551                         float centerWeight,BOOLEAN lengthNormalize,float topToBottom,
552                         FILE *pathFP)
553 {
554     Direction path[MAX_SIGNAL_LENGTH][MAX_SIGNAL_LENGTH],*pc;
555     float costs0[MAX_SIGNAL_LENGTH+2];
556     float costs1[MAX_SIGNAL_LENGTH+2];
557     float costs2[MAX_SIGNAL_LENGTH+2];
558     float slope,minVal;
559     int i,j;
560     int bottom,top;
561     float *cd1l1,*cd2l1,*cd1l2;
562     float *a1c,*a2c,*cd,*cl,*cdl,*dc;
563     float b1v,b2v,returnVal;
564
565     /* printf("sc:\n"); */
566
567     if (aLength>MAX_SIGNAL_LENGTH||bLength>MAX_SIGNAL_LENGTH)
568         DoError("SlopeCMatch: maximum signal length exceeded.\n",NULL);
569
570     slope = (float)aLength/(float)bLength;
571     if ((slope>MAX_SLOPE)||((1/slope)>MAX_SLOPE)) {
572         return BIG_NUM;
573     }
574
575     for (i=0;i<aLength+2;++i) {
576         costs2[i] = BIG_NUM;
577         costs1[i] = BIG_NUM;
578         costs0[i] = BIG_NUM;
579     }
580
581     pc = &(path[0][0]);
582     *pc++ = NONE;
583     costs0[2] = SquareDifference(*a1,*b1)*topToBottom+SquareDifference(*a2,*b2);
584
585     for (i=1;i<bLength;++i) {
586         bottom = IMax(i/2,2*i+aLength-2*bLength);
587         top = IMin(2*i,i/2+aLength-bLength/2)+1;
588
589         a1c = a1+bottom; /* a1 cursor */
590         a2c = a2+bottom; /* a2 cursor */
591         b1v = *(b1+i); /* b1 value */
592         b2v = *(b2+i); /* b2 value */
593
594         switch (i%3) {
595             case 0:
596                 dc = costs0+bottom-2+2;
597                 cd2l1 = costs2+bottom-2+2;

```

```

598     cd1l2 = costs1 + bottom-1 + 2;
599     cd1l1 = costs2 + bottom-1 + 2;
600     break;
601 case 1:
602     dc = costs1 + bottom-2 + 2;
603     cd2l1 = costs0 + bottom-2 + 2;
604     cd1l2 = costs2 + bottom-1 + 2;
605     cd1l1 = costs0 + bottom-1 + 2;
606     break;
607 case 2:
608     dc = costs2 + bottom-2 + 2;
609     cd2l1 = costs1 + bottom-2 + 2;
610     cd1l2 = costs0 + bottom-1 + 2;
611     cd1l1 = costs1 + bottom-1 + 2;
612     break;
613 }
614 *dc++ = BIG_NUM;
615 *dc++ = BIG_NUM;
616 pc = &(path[i][bottom]);
617 for (j=bottom; j<top; ++j) {
618     float d2l1,d1l2,d1l1,rest;
619
620     rest = SquareDifference(*a1c++ ,b1v)*topToBottom +
621           SquareDifference(*a2c++ ,b2v);
622     d1l1 = *cd1l1++ + rest*centerWeight;
623     d1l2 = *cd1l2++ + rest;
624     d2l1 = *cd2l1++ + rest;
625
626     if (d1l1<d1l2)
627         if (d1l1<d2l1) {
628             *dc++ = d1l1;
629             *pc++ = D1L1;
630         }
631         else {
632             *dc++ = d2l1;
633             *pc++ = D2L1;
634         }
635     else
636         if (d1l2<d2l1) {
637             *dc++ = d1l2;
638             *pc++ = D1L2;
639         }
640         else {
641             *dc++ = d2l1;
642             *pc++ = D2L1;
643         }
644 }
645
646 switch (i%3) {
647 case 0:
648     dc = costs0;
649     break;
650 case 1:
651     dc = costs1;
652     break;

```

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```

653     case 2:
654         dc = costs2;
655         break;
656     }
657     minVal = BIG_NUM;
658     printf("%6d: ",i);
659     for (j=0;j<aLength+2;++j) {
660         if (*dc <= minVal)
661             minVal = *dc;
662         if (*dc++ >= BIG_NUM)
663             printf(" ");
664         else
665             printf("*");
666     }
667     printf(" %6.2f\n",minVal);
668 }
669
670 --i;
671 switch (i%3) {
672 case 0:
673     dc = costs0;
674     break;
675 case 1:
676     dc = costs1;
677     break;
678 case 2:
679     dc = costs2;
680     break;
681 }
682 returnVal = *(dc+aLength-1+2);
683
684 PrintPath(a1,a2,aLength,b1,b2,bLength,path,i,returnVal,pathFP);
685
686 if (lengthNormalize)
687     return returnVal/sqrt(aLength*aLength+bLength*bLength);
688 else
689     return returnVal;
690 }
691

```

Jul 31 17:14 1991 single.c

```

1  #include <stdio.h>
2  #include "mylib.h"
3  #include "types.h"
4  #include "dict.h"
5  #include "diff.h"
6  #include "match.h"
7  #include "matchparallel.h"
8
9  main(argc, argv)
10 int argc;
11 char *argv[];
12 {
13     char *dictFile1,*dictFile2,*outFile;
14     int shape1,shape2;
15     Dictionary dict1,dict2;
16     float score;
17     char *matchType;
18     float centerWeight,normalBandWidth,topToBottom,hillToValleyLocal;
19     DiffDescriptorBody dd;
20     FILE *pathFP;
21     BOOLEAN
22     useL2,slopeConstrain,warp,lengthNormalize,topToBottomOption,hillToValleyOption;
23     BOOLEAN separate;
24
25     centerWeight = 1.0;
26     normalBandWidth = 20;
27     topToBottom = 1.0;
28     hillToValleyLocal = 1.0;
29     DefArg("%s %d %s %d %s", "dict1 shape1 dict2 shape2 outfile", &dictFile1, &shape1,
30           &dictFile2, &shape2, &outFile);
31     DefOption("-L2", "-L2", &useL2);
32     DefOption("-slopeConstrain %f", "-slopeConstrain <center weight> ",
33           &slopeConstrain, &centerWeight);
34     DefOption("-warp %f %f", "-warp <center weight> <band width> ",
35           &warp, &centerWeight, &normalBandWidth);
36     DefOption("-separate", "-separate", &separate);
37     DefOption("-normalize", "-normalize", &lengthNormalize);
38     DefOption("-topToBottom %f", "-topToBottom
39     <ratio> ", &topToBottomOption, &topToBottom);
40     DefOption("-hillToValley %f", "-hillToValley
41     <ratio> ", &hillToValleyOption, &hillToValleyLocal);
42     ScanArgs(argc, argv);
43
44     dict1 = ReadDictionary(dictFile1);
45     dict2 = ReadDictionary(dictFile2);
46
47     if ((shape1 >= dict1->numberOfEntries) || (shape1 < 0) ||
48         (shape2 >= dict2->numberOfEntries) || (shape2 < 0))
49         DoError("%s: bad shape number.\n", argv[0]);
50
51     if ((pathFP=fopen(outFile, "w"))==NULL)
52         DoError("single: error opening output file %s.\n", outFile);

```

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```

50
51     if (useL2) {
52         fprintf(stdout, "Using L2 on length normalized shapes.\n");
53         dd.diffType = L2;
54     }
55     else if (slopeConstrain) {
56         fprintf(stdout, "Using dynamic time warping with slope constrained to [0.5,2].\n");
57         dd.diffType = CONSTRAINED;
58         dd.separate = separate;
59         if (separate)
60             fprintf(stdout, "Top and bottom warped separately.\n");
61         else
62             fprintf(stdout, "Top and bottom warped together.\n");
63     }
64     else {
65         fprintf(stdout, "Using dynamic time warping with bandwidth %d.\n", normalBandWidth);
66         dd.diffType = WARP;
67         dd.bandWidth = normalBandWidth;
68         dd.separate = separate;
69         if (separate)
70             fprintf(stdout, "Top and bottom warped separately.\n");
71         else
72             fprintf(stdout, "Top and bottom warped together.\n");
73     }
74     if (!useL2) {
75         fprintf(stdout, "Center weight = %f.\n", centerWeight);
76         dd.centerWeight = centerWeight;
77         if (lengthNormalize) {
78             dd.lengthNormalize = TRUE;
79             fprintf(stdout, "Scores normalized by signal length.\n");
80         }
81         else
82             dd.lengthNormalize = FALSE;
83     }
84     dd.hillToValley = hillToValleyLocal;
85     dd.topToBottom = topToBottom;
86     dd.pathFP = pathFP;
87     fprintf(stdout, "Top to bottom ratio = %6.2f.\n", topToBottom);
88     fprintf(stdout, "Hill to Valley ratio = %6.2f.\n", hillToValleyLocal);
89
90     score = DiffPair(*(dict1->outlines+shape1),
91                     *(dict2->outlines+shape2),
92                     &dd);
93
94     fclose(pathFP);
95
96     printf("Score = %f\n", score);
97 }

```

Section C

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Jul 23 20:24 1991 slopeMatch.c

```
1    float SlopeConstrainedMatch(float *a1,float *a2,int aLength,  
2                                float *b1,float *b2,int bLength,  
3                                float maxSlope)  
4    {  
5        float costs[MAX_SIGNAL_LENGTH][MAX_SIGNAL_LENGTH];  
6        char down[MAX_SIGNAL_LENGTH][MAX_SIGNAL_LENGTH];  
7        char left[MAX_SIGNAL_LENGTH][MAX_SIGNAL_LENGTH];  
8    }
```

Jul 12 14:36 1991 sortMatrix.c

```

1  #include <stdio.h>
2  #include "error.h"
3  #include "pict.h"
4
5  #define MAX_ENTRIES 5000
6
7  typedef struct {
8      float score;
9      int x;
10     int y;
11 } *CompareTuple, CompareTupleBody;
12
13 int TupleLessThan(CompareTuple *x, CompareTuple *y)
14 {
15     if ((*x)->score == (*y)->score)
16         return 0;
17     else if ((*x)->score < (*y)->score)
18         return -1;
19     else
20         return 1;
21 }
22
23 void PrintTuple(CompareTuple a, FILE *fp)
24 {
25     fprintf(fp, "(%d,%d): %f\n", a->x, a->y, a->score);
26 }
27
28 void main(int argc, char **argv)
29 {
30     Picture pict;
31     int i, j;
32     int x, y;
33     char *infile;
34     CompareTuple scores[MAX_ENTRIES];
35
36     if (argc != 2)
37         DoError("Usage: %s infile.\n", argv[0]);
38     infile = argv[1];
39
40     pict = load_pict(infile);
41     if (pict->width*pict->height > MAX_ENTRIES)
42         DoError("%s: matrix has too manyt entries.\n", argv[0]);
43
44     for (y=0; y<pict->height; ++y)
45         for (x=0; x<pict->width; ++x) {
46             CompareTuple temp;
47             temp = (CompareTuple)calloc(1, sizeof(CompareTupleBody));
48             if (temp == NULL)
49                 DoError("%s: cannot allocate space.\n", argv[0]);
50             temp->score = *((float *) (pict->data) + x + y*pict->width);
51             temp->x = x;
52             temp->y = y;

```

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```
53     scores[i] = temp;
54     ++i;
55 }
56 qsort(scores,i,sizeof(CompareTuple),TupleLessThan);
57 for (j=0;j<i; ++j)
58     PrintTuple(scores[j],stdout);
59 }
60
```


Section D

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Aug 26 17:54 1991 Makefile

```

1  CCFLAGS = -g -c -I/net/piglet/piglet-1c/hopcroft/new/include
2
3  OFUNS = blobify.o orient.o lines.o newBaselines.o newMain.o types.o \
4  newBlobify.o boxes.o newContour.o numbers.o fontNorm.o \
5  dict.o
6
7  ALPHAOFUNS = orient.o lines.o baselines.o newMain.o types.o \
8  blobify.o boxes.o newContour.o numbers.o alphaNorm.o \
9  dict.o
10
11
12  SOURCES = Makefile baselines.c blobify.c boxes.c dict.c dmain.c getAll.c\
13  getOutline.c lines.c newContour.c newDiff2.c newMain.c\
14  numbers.c orient.c overlay.c fontNorm.c testFine.c types.c
15
16  EXTRNS = /net/piglet/piglet-1c/hopcroft/error/error.o\
17  /net/piglet/piglet-1c/hopcroft/new/pict/pict.o \
18  /net/piglet/piglet-1c/hopcroft/lists/lists.o
19
20  INCLUDE = /net/piglet/piglet-1c/hopcroft/new/include/
21  MISC = $(INCLUDE)misc.h
22  BOOLEAN = $(INCLUDE)boolean.h
23  LINES = $(INCLUDE)lines.h
24  LISTS = $(INCLUDE)lists.h
25  PICT = $(INCLUDE)pict.h
26  TYPES = $(INCLUDE)types.h
27  MYLIB = $(INCLUDE)mylib.h
28  ORIENT = $(INCLUDE)orient.h
29  BASELINES = $(INCLUDE)baselines.h
30  BLOBIFY = $(INCLUDE)blobify.h
31  BOXES = $(INCLUDE)boxes.h
32  CONTOUR = $(INCLUDE)newContour.h
33  DIFF = $(INCLUDE)diff.h
34  DICT = $(INCLUDE)dict.h
35  ERROR = $(INCLUDE)error.h
36  FONTNORM = $(INCLUDE)fontNorm.h
37
38  orient:    $(OFUNS)
39      gcc $(OFUNS) $(HOME)/new/lib/mylib.a /usr/lib/debug/malloc.o -lm -o $@
40
41  newBlobify: newBlobify.o
42      gcc newBlobify.o ../lib/mylib.a -lm -o $@
43
44  makeAlphabet:    $(ALPHAOFUNS)
45      gcc $(ALPHAOFUNS) /usr/lib/debug/malloc.o $(EXTRNS) -lm -o $@
46
47  overlay:    overlay.o
48      gcc overlay.o $(EXTRNS) -o $@
49
50  testFine:    testFine.o lines.o guassian.o types.o
51      gcc testFine.o lines.o guassian.o types.o $(EXTRNS) -lm -o $@
52

```

```

53 boxes: boxes.o lines.o types.o
54 gcc boxes.o lines.o types.o $(HOME)/new/lib/mylib.a -lm -o $@
55
56 getOutline: dict.o getOutline.o
57 gcc getOutline.o dict.o $(EXTRNS) -lm -o $@
58
59 getAll: dict.o getAll.o
60 gcc getAll.o dict.o $(EXTRNS) -lm -o $@
61
62 maxFilter: maxFilter.o
63 gcc maxFilter.o $(HOME)/new/lib/mylib.a -lm -o $@
64
65 myWc: myWc.o
66 gcc myWc.o $(EXTRNS) -o $@
67
68 printCode: $(SOURCES)
69 /usr/bin/pr -n3 $(SOURCES) | lpr -PWeeklyWorldNews
70
71 newBaselines.o: newBaselines.c $(BOOLEAN) $(PICT) $(TYPES) $(LISTS) $(LINES)\
72 $(BASELINES)
73 gcc $(CCFLAGS) newBaselines.c
74
75 blobify.o: blobify.c $(BOOLEAN) $(PICT) $(BLOBIFY)
76 gcc $(CCFLAGS) blobify.c
77
78 boxes.o: boxes.c $(BOOLEAN) $(PICT) $(TYPES) $(BOXES)
79 gcc $(CCFLAGS) boxes.c
80
81 dict.o: dict.c $(BOOLEAN) $(TYPES) $(ERROR) $(PICT) $(DICT)
82 gcc $(CCFLAGS) dict.c
83
84 dmain.o: dmain.c $(BOOLEAN) $(PICT) $(DIFF)
85 gcc $(CCFLAGS) dmain.c
86
87 getAll.o: getAll.c $(BOOLEAN) $(TYPES) $(PICT) $(DICT)
88 gcc $(CCFLAGS) getAll.c
89
90 getOutline.o: getOutline.c $(BOOLEAN) $(TYPES) $(PICT) $(DICT)
91 gcc $(CCFLAGS) getOutline.c
92
93 guassian.o: guassian.c
94 gcc $(CCFLAGS) guassian.c
95
96 lines.o: lines.c $(BOOLEAN) $(PICT) $(LINES)
97 gcc $(CCFLAGS) lines.c
98
99 maxFilter.o: maxFilter.c $(MYLIB)
100 gcc $(CCFLAGS) maxFilter.c
101
102 myWc.o: myWc.c $(BOOLEAN) $(ERROR)
103 gcc $(CCFLAGS) myWc.c
104
105 newBlobify.o: newBlobify.c $(MYLIB) $(BLOBIFY)
106 gcc $(CCFLAGS) newBlobify.c
107

```

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```

108 newContour.o: newContour.c $(BOOLEAN) $(PICT) $(TYPES) $(LINES) \
109 $(LISTS) $(CONTOUR) $(FONTNORM)
110 gcc $(CCFLAGS) newContour.c
111
112 newDiff2.o: newDiff2.c $(BOOLEAN) $(TYPES) $(PICT) $(DIFF)
113 gcc $(CCFLAGS) newDiff2.c
114
115 newMain.o: newMain.c $(BOOLEAN) $(PICT) $(LISTS) $(LINES) \
116 $(ORIENT) $(BASELINES) $(BLOBIFY) $(BOXES) $(CONTOUR) $(ORIENT)
117 gcc $(CCFLAGS) newMain.c
118
119 numbers.o: numbers.c $(BOOLEAN) $(PICT) $(LINES)
120 gcc $(CCFLAGS) numbers.c
121
122 orient.o: orient.c $(BOOLEAN) $(TYPES) $(PICT) $(ORIENT) $(LINES)
123 gcc $(CCFLAGS) orient.c
124
125 overlay.o: overlay.c $(BOOLEAN) $(PICT)
126 gcc $(CCFLAGS) overlay.c
127
128 postproc.o: postproc.c $(BOOLEAN) $(TYPES) $(ERROR) $(PICT) $(DICT)
129 gcc $(CCFLAGS) postproc.c
130
131 alphaNorm.o: alphaNorm.c $(BOOLEAN) $(TYPES) $(ERROR) $(PICT) $(DICT) $(FONTNORM)
132 gcc $(CCFLAGS) alphaNorm.c
133
134 fontNorm.o: fontNorm.c $(BOOLEAN) $(TYPES) $(ERROR) $(PICT) $(DICT) $(FONTNORM)
135 gcc $(CCFLAGS) fontNorm.c
136
137 testFine.o: testFine.c
138 gcc $(CCFLAGS) testFine.c
139
140 types.o: types.c $(TYPES) $(ERROR)
141 gcc $(CCFLAGS) types.c
142

```

Aug 5 15:45 1991 alphaNorm.c

```

1  #include <stdio.h>
2  #include <math.h>
3  #include "boolean.h"
4  #include "types.h"
5  #include "error.h"
6  #include "pict.h"
7  #include "dict.h"
8  #include "fontNorm.h"
9
10 /* This file is just like fontNorm.c, but assumes that the input is data for an alphabet
    dictionary.
11  * This data is
12  *
13  * a-z
14  *
15  * A-Z
16  *
17  * 0-9
18  *
19  * |!@#$$%^&*() + \ - = {} | ; : / < > ?
20  *
21  * ' ' ~ -
22  *
23  * _
24  *
25  * The x height will be measured from the x(23). The ascender height will be measured
26  * from the l(11).
27  */
28
29 #define X_HEIGHT_SHAPE 23
30 #define ASC_HEIGHT_SHAPE 11
31
32 extern double ceil(double);
33 extern int irint(double);
34
35
36 #define UP 0
37 #define DOWN 1
38 typedef int Direction;
39
40 extern Picture thePict;
41
42 void StoreRawOutlinePair(Dictionary dict, int dictEntry,
43                          Box box, int *bothX, int *topY, int *baseY,
44                          int numberOfLegs)
45 {
46     RawOutlinePair temp;
47     int i;
48     int *xCursor, *topCursor, *bottomCursor;
49
50     temp = (RawOutlinePair) calloc(1, sizeof(RawOutlinePairBody));
51     if (temp == NULL)

```

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```

52     DoError("StoreRawOutlinePair: cannot allocate space\n",NULL);
53
54     temp->box = box;
55     temp->numberOfLegs = numberOfLegs;
56
57     temp->x = (int *)calloc(temp->numberOfLegs,sizeof(int));
58     temp->top = (int *)calloc(temp->numberOfLegs,sizeof(int));
59     temp->bottom = (int *)calloc(temp->numberOfLegs,sizeof(int));
60     if ((temp->x == NULL) ||
61         (temp->top == NULL) ||
62         (temp->bottom == NULL))
63         DoError("StoreRawOutlinePair: cannot allocate space\n",NULL);
64
65     xCursor = temp->x;
66     topCursor = temp->top;
67     bottomCursor = temp->bottom;
68
69     for (i=0;i<numberOfLegs; ++i) {
70         *xCursor++ = *bothX++;
71         *topCursor++ = *topY++;
72         *bottomCursor++ = *baseY++;
73     }
74     *(dict->rawOutlines+dictEntry) = temp;
75 }
76
77 int RawOutlineWidth(RawOutlinePair a,int middleLine)
78 {
79     int i,numberOfLegs,right,left;
80     int *topCursor,*bottomCursor;
81     int topValue,bottomValue;
82
83     numberOfLegs = a->numberOfLegs;
84
85     topCursor = a->top;
86     bottomCursor = a->bottom;
87     for (i=0;i<numberOfLegs; ++i) {
88         topValue = *topCursor++;
89         bottomValue = *bottomCursor++;
90
91         if (topValue != HIT_THE_BOX) {
92             topValue = middleLine - topValue;
93             if (topValue < 0)
94                 topValue = 0;
95         }
96         else
97             topValue = 0;
98
99         if (bottomValue != HIT_THE_BOX) {
100             bottomValue = bottomValue - middleLine;
101             if (bottomValue < 0)
102                 bottomValue = 0;
103         }
104         else
105             bottomValue = 0;
106

```

```

107     if ((bottomValue != 0) || (topValue != 0))
108         break;
109     }
110     left = i;
111
112     topCursor = a->top + numberOfLegs-1;
113     bottomCursor = a->bottom + numberOfLegs-1;
114     for (i = numberOfLegs-1; i >= 0; --i) {
115         topValue = *topCursor--;
116         bottomValue = *bottomCursor--;
117
118         if (topValue != HIT_THE_BOX) {
119             topValue = middleLine - topValue;
120             if (topValue < 0)
121                 topValue = 0;
122         }
123         else
124             topValue = 0;
125
126         if (bottomValue != HIT_THE_BOX) {
127             bottomValue = bottomValue - middleLine;
128             if (bottomValue < 0)
129                 bottomValue = 0;
130         }
131         else bottomValue = 0;
132
133         if ((topValue != 0) || (bottomValue != 0))
134             break;
135     }
136     right = i + 1;
137
138     return right-left;
139 }
140
141 void ResampleOutlinePair(OutlinePair a, float newToOldFactor)
142 /* Resample an outline pair using linear interpolation. */
143 {
144     int newWidth, oldWidth, i;
145     int oldLeft, oldRight;
146     float oldCenter;
147     float *newX, *newTop, *newBottom;
148     float *xCursor, *topCursor, *bottomCursor;
149
150     oldWidth = a->numberOfLegs;
151     newWidth = irint(newToOldFactor*oldWidth);
152
153     newX = (float *)calloc(newWidth, sizeof(float));
154     newTop = (float *)calloc(newWidth, sizeof(float));
155     newBottom = (float *)calloc(newWidth, sizeof(float));
156     if ((newX == NULL) || (newTop == NULL) || (newBottom == NULL))
157         DoError("ResampleOutlinePair: cannot allocate space.\n", NULL);
158
159     xCursor = newX;
160     topCursor = newTop;
161     bottomCursor = newBottom;

```

```

162
163     for (i=0; i<newWidth; ++i) {
164         oldCenter = i/(float)newWidth*(float)oldWidth;
165         oldLeft = irint(floor(oldCenter));
166         oldRight = irint(ceil(oldCenter));
167         if (oldLeft == oldRight) {
168             *xCursor++ = *(a->x+oldLeft);
169             *topCursor++ = *(a->top+oldLeft);
170             *bottomCursor++ = *(a->bottom+oldLeft);
171         }
172         else {
173             float slope;
174             slope = *(a->x+oldRight)-*(a->x+oldLeft);
175             *xCursor++ = *(a->x+oldLeft) + (oldCenter-oldLeft)*slope;
176             slope = *(a->top+oldRight)-*(a->top+oldLeft);
177             *topCursor++ = *(a->top+oldLeft) + (oldCenter-oldLeft)*slope;
178             slope = *(a->bottom+oldRight)-*(a->bottom+oldLeft);
179             *bottomCursor++ = *(a->bottom+oldLeft) + (oldCenter-oldLeft)*slope;
180         }
181     }
182
183     free(a->x);
184     free(a->top);
185     free(a->bottom);
186
187     a->x = newX;
188     a->top = newTop;
189     a->bottom = newBottom;
190     a->numberOfLegs = newWidth;
191 }
192
193 void StoreOutlinePair(Dictionary dict, int dictEntry,
194                     int middleLine, int fontXHeight,
195                     int ascenderHeight)
196 /* This routine normalizes the raw outline pair stored in dict at dictEntry using the following
197  * operations:
198  * 1) For the top contour, shift so that the middle line is at y=0 and negate so that the
199  *    higher points are greater than 0. For the bottom, shift so that middle line is at y=0,
200  *    but don't flip. Thus, lower points have y coordinates greater than 0.
201  *    Consider points whose value is HIT_THE_BOX to be at y=0. These correspond to gaps
202  *    between the letters.
203  * 2) Compress top and bottom y coordinates by 1/fontXHeight so that the coordinates at
204  *    the
205  *    distance of the fontXHeight have value 1. Note that 1 is an arbitrary number. It is
206  *    unlikely that a signal will have parts that are the x height above the center line
207  *    anyway.
208  *    FOR TOP CONTOUR,
209  *    IF HEIGHT IS GREATER THAN XHEIGHT, SCALE DIFFERENCE BY 1.5/ASCENDER_HEIGHT.
210  *    ELSE SCALE DIFFERENCE BY 1/XHEIGHT.
211  *    FOR BOTTOM CONTOUR,
212  *    SCALE BY 1.5/ASCENDER_HEIGHT.
213  * 3) Compress the x coordinates by the same factor as in step 2. Note that this does not
214  *    actually resample the contour. NOW DO THIS WITH RESAMPLE. USE SCALE FACTOR OF
215  *    20/XHEIGHT.
216  * 4) Remove left and right ends of the contour that have y values of zero. This is so the

```

```

216 * contour starts where the word starts, rather than at the edge of its bounding box.
217 * 5) Resample the contour to stretch by firstFontXwidth/fontxWidth. KILL THIS
OPERATION.
218 */
219 {
220     RawOutlinePair raw;
221     OutlinePair temp;
222     int i,numberOfLegs;
223     int y;
224     int offset;

225     int *xSCursor,*topSCursor,*bottomSCursor;
226     float *xDCursor,*topDCursor,*bottomDCursor;
227     float *xCursor,*topCursor,*bottomCursor;
228     int left,right;
229     float foffset;
230
231     raw = *(dict->rawOutlines+dictEntry);
232
233     temp = (OutlinePair)calloc(1,sizeof(OutlinePairBody));
234     if (temp == NULL)
235         DoError("StoreOutlinePair: cannot allocate space\n",NULL);
236
237     temp->x = (float *)calloc(raw->numberOfLegs,sizeof(float));
238     temp->top = (float *)calloc(raw->numberOfLegs,sizeof(float));
239     temp->bottom = (float *)calloc(raw->numberOfLegs,sizeof(float));
240     if ((temp->x == NULL) ||
241         (temp->top == NULL) ||
242         (temp->bottom == NULL))
243         DoError("StoreOutlinePair: cannot allocate space\n",NULL);
244
245     temp->box = raw->box;
246     temp->blackoutHeight = 0;
247     temp->numberOfLegs = raw->numberOfLegs;
248     offset = temp->offset = *(raw->x);
249     temp->width = *(raw->x+raw->numberOfLegs-1) - temp->offset;
250
251     xDCursor = temp->x;
252     topDCursor = temp->top;
253     bottomDCursor = temp->bottom;
254     xSCursor = raw->x;
255     topSCursor = raw->top;
256     bottomSCursor = raw->bottom;
257
258     numberOfLegs = raw->numberOfLegs;
259     for (i=0;i<numberOfLegs; ++i) {
260         /* *xDCursor++ = (float)(*xSCursor++ - offset)/fontXHeight; */
261         if (*topSCursor==HIT_THE_BOX) {
262             y = 0;
263             topSCursor++;
264         }
265         else {
266             y = middleLine - *topSCursor++;
267             if (y<0)
268                 y = 0;

```



```

269     }
270     if (y > fontXHeight/2)
271         *topDCursor++ = (float)y * 1.5 / ascenderHeight;
272     else
273         *topDCursor++ = (float)y / fontXHeight;
274
275     if (*bottomSCursor == HIT_THE_BOX) {
276         y = 0;
277         bottomSCursor++;
278     }
279     else {
280         y = *bottomSCursor++ - middleLine;
281         if (y < 0)
282             y = 0;
283     }
284     if (y > fontXHeight/2)
285         *bottomDCursor++ = (float)y / fontXHeight;
286     else
287         *bottomDCursor++ = (float)y * 1.5 / ascenderHeight;
288 }
289
290 /* Now try to remove parts of the contour on to the left and right of the
291    * word shape that are at height 0 */
292
293 /* Find left edge */
294 topDCursor = temp->top;
295 bottomDCursor = temp->bottom;
296 for (i=0; i<numberOfLegs; ++i) {
297     if ((*topDCursor++ != 0) || (*bottomDCursor++ != 0))
298         break;
299 }
300 left = i;
301
302 /* Find right edge */
303 topDCursor = temp->top + numberOfLegs - 1;
304 bottomDCursor = temp->bottom + numberOfLegs - 1;
305 for (i=numberOfLegs-1; i>=0; --i) {
306     if ((*topDCursor-- != 0) || (*bottomDCursor-- != 0))
307         break;
308 }
309 right = i + 1;
310
311 /* Clip the ends of the contour at left and right */
312 xDCursor = temp->x;
313 topDCursor = temp->top;
314 bottomDCursor = temp->bottom;
315 xCursor = temp->x + left;
316 topCursor = temp->top + left;
317 bottomCursor = temp->bottom + left;
318 offset = *xSCursor;
319 for (i=left; i<right; ++i) {
320     *xDCursor++ = *xCursor++ - offset;
321     *topDCursor++ = *topCursor++;
322     *bottomDCursor++ = *bottomCursor++;
323 }

```

```

324     temp->numberOfLegs = right-left;
325
326     *(dict->outlines+dictEntry) = temp;
327     ResampleOutlinePair(*(dict->outlines+dictEntry),(float)20/(float)fontXHeight);
328 }
329
330 static int lineSpacing;
331 int OrderOutlinePair(OutlinePair *o1,OutlinePair *o2)
332 {
333     int yDistance;
334     int xDistance;
335     yDistance = (*o1)->box->pageY - (*o2)->box->pageY;
336     if (yDistance<lineSpacing && yDistance > -lineSpacing) {
337         xDistance = (*o1)->box->pageX - (*o2)->box->pageX;
338         return xDistance;
339     }
340     return yDistance;
341 }
342
343 void SortDictionary(Dictionary dict)
344 {
345     lineSpacing = 20;
346     qsort(dict->rawOutlines,dict->numberOfEntries,sizeof(RawOutlinePair),
347         OrderOutlinePair);
348 }
349
350 /* WARNING - assumes at least on entry is not equal to HIT_THE_BOX */
351 float MaxTopValue(RawOutlinePair o)
352 {
353     int i;
354     float maxValue;
355     maxValue = *(o->top);
356     for (i=0;i<o->numberOfLegs; ++i)
357         if (*(o->top+i)>maxValue && *(o->top+i)!=HIT_THE_BOX)
358             maxValue = *(o->top+i);
359     return maxValue;
360 }
361
362 /* WARNING - assumes at least on entry is not equal to HIT_THE_BOX */
363 float MinTopValue(RawOutlinePair o)
364 {
365     int i;
366     float minValue;
367     minValue = *(o->top);
368     for (i=0;i<o->numberOfLegs; ++i)
369         if (*(o->top+i)<minValue && *(o->top+i)!=HIT_THE_BOX)
370             minValue = *(o->top+i);
371     return minValue;
372 }
373
374 #define HIST_SIZE 100
375 void HistogramMax(int *data,int dataLength,int offset,int sign,int *histogram)
376 {
377     int i,bin;
378

```

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```

379     if (sign>0) {
380         int maxValue;
381
382         maxValue = *data;
383         for (i=0;i<dataLength; ++i)
384             if (data[i]!=HIT_THE_BOX) {
385                 maxValue = data[i];
386                 break;
387             }
388         for (;i<dataLength; ++i)
389             if (data[i]!=HIT_THE_BOX && data[i]>maxValue)
390                 maxValue = data[i];
391         if (maxValue != HIT_THE_BOX) {
392             bin = maxValue-offset;
393             if ((bin>=0)&&(bin<HIST_SIZE))
394                 histogram[bin] ++;
395         }
396     }
397     else {
398         int minValue;
399         minValue = *data;
400         for (i=0;i<dataLength; ++i)
401             if (data[i]!=HIT_THE_BOX) {
402                 minValue = data[i];
403                 break;
404             }
405         for (;i<dataLength; ++i)
406             if (data[i]!=HIT_THE_BOX && data[i]<minValue)
407                 minValue = data[i];
408         if (minValue != HIT_THE_BOX) {
409             bin = minValue-offset;
410             if ((bin>=0)&&(bin<HIST_SIZE))
411                 histogram[bin] ++;
412         }
413     }
414 }
415
416 void Histogram(int *data,int dataLength, int offset, int *histogram)
417 {
418     int i,bin;
419
420     for (i=0;i<dataLength; ++i) {
421         if (*data != HIT_THE_BOX) {
422             bin = *data-offset;
423             if ((bin>=0)&&(bin<HIST_SIZE))
424                 histogram[bin] ++;
425         }
426         data ++;
427     }
428 }
429
430 int MaxBin(int *histogram)
431 {
432     int i;
433     int maxValue;

```

```

434     int maxIndex;
435
436     maxValue = histogram[0];
437     maxIndex = 0;
438     for (i=0;i<HIST_SIZE; ++ i)
439         if (histogram[i]>maxValue) {
440             maxValue = histogram[i];
441             maxIndex = i;
442         }
443     return maxIndex;
444 }
445
446 int MaxBinAbove(int *histogram,int line)
447 {
448     int i;
449     int maxValue;
450     int maxIndex;
451     int top,bottom;
452
453     for (i=0;i<HIST_SIZE; ++ i)
454         if (histogram[i] != 0)
455             break;
456
457     top = i;
458     bottom = (line+top)/2;
459
460     maxValue = histogram[top];
461     maxIndex = top;
462     for (i=top;i<=bottom; ++ i)
463         if (histogram[i]>maxValue) {
464             maxValue = histogram[i];
465             maxIndex = i;
466         }
467     return maxIndex;
468 }
469
470 void DrawTextLines(Picture thePict,Dictionary dict,int topLine,int bottomLine)
471 {
472     int maxLength;
473     int halfWidth;
474     int x,y;
475     float x2,x3,y2,y3;
476     float angle;
477
478     angle = (*(dict->rawOutlines))->box->angle;
479     maxLength = thePict->width+thePict->height;
480     halfWidth = thePict->width / 2;
481     x = topLine * -sin(angle) + halfWidth * cos(angle);
482     y = topLine * cos(angle) + halfWidth * sin(angle);
483     x2 = x + maxLength*cos(angle);
484     y2 = y + maxLength*sin(angle);
485     x3 = x-maxLength*cos(angle);
486     y3 = y-maxLength*sin(angle);
487     DrawLine(thePict,x,y,(int)x2,(int)y2,5);
488     DrawLine(thePict,x,y,(int)x3,(int)y3,5);

```

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```

489
490     x = bottomLine * -sin(angle) + halfWidth * cos(angle);
491     y = bottomLine * cos(angle) + halfWidth * sin(angle);
492     x2 = x + maxLength*cos(angle);
493     y2 = y + maxLength*sin(angle);
494     x3 = x - maxLength*cos(angle);
495     y3 = y - maxLength*sin(angle);
496     DrawLine(thePict,x,y,(int)x2,(int)y2,5);
497     DrawLine(thePict,x,y,(int)x3,(int)y3,5);
498 }
499
500 void PageStatistics(Dictionary dict,char *fileName)
501 /* WARNING - this must be run before PostProcess since PostProcess changes the raw
502  * shape data. */
503 {
504     int index;
505     int temp;
506     int i,startIndex,firstY,minY,endIndex,shape;
507     int tops[HIST_SIZE];
508     int bottoms[HIST_SIZE];
509     int ascenders[HIST_SIZE];
510     int descenders[HIST_SIZE];
511     int middleLine,topLine,bottomLine,ascenderLine,descenderLine;
512     int ascenderHeight,descenderHeight,lineNumber;
513     int fontXHeight,fontXWidth,xIndex;
514     RawOutlinePair thisShape;
515     FILE *fp;
516     BOOLEAN haveFirstFontXWidth = FALSE;
517     int firstFontXWidth;
518
519     if ((fp=fopen(fileName,"w")) == NULL)
520         DoError("PageStatistics: error opening output file %s.\n",fileName);
521
522     SortDictionary(dict);
523
524     index = 0;
525     lineNumber = 0;
526     while (index < dict->numberOfEntries) {
527         startIndex = index;
528         firstY = (*(dict->rawOutlines + index))->box->pageY;
529         minY = firstY;
530         while ( (*(dict->rawOutlines + index))->box->pageY - firstY < 20 &&
531                (*(dict->rawOutlines + index))->box->pageY - firstY > -20) {
532             if (minY > (*(dict->rawOutlines + index))->box->pageY)
533                 minY = (*(dict->rawOutlines + index))->box->pageY;
534             ++index;
535             if (index == dict->numberOfEntries)
536                 break;
537         }
538         endIndex = index;
539
540
541         /* shapes from start index through endIndex are all on */
542         /* the same text line */
543         /* minY has the top of the highest box on the line. */

```

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```

544
545 /* Find the base and topline by taking the mode of the heights of the
546 * valleys of the bottom contours and the peaks of the top contours */
547 for (i=0;i<HIST_SIZE;i++) {
548     bottoms[i]=0;
549 }
550
551 for (shape=startIndex;shape<endIndex; ++shape) {
552     thisShape = *(dict->rawOutlines+shape);
553     Histogram(thisShape->bottom,thisShape->numberOfLegs,minY,bottoms);
554 }
555 bottomLine = MaxBin(bottoms)+minY;
556 if (X_HEIGHT_SHAPE>=startIndex&&X_HEIGHT_SHAPE<endIndex) {
557     topLine = MinTopValue(*(dict->rawOutlines+X_HEIGHT_SHAPE));
558     fontXHeight = bottomLine - topLine;
559 }
560 if (ASC_HEIGHT_SHAPE>=startIndex&&ASC_HEIGHT_SHAPE<endIndex) {
561     ascenderLine = MinTopValue(*(dict->rawOutlines+ASC_HEIGHT_SHAPE));
562     ascenderHeight = bottomLine - ascenderLine;
563 }
564 middleLine = bottomLine-fontXHeight/2;
565 topLine = bottomLine-fontXHeight;
566
567 if (thePict)
568     DrawTextLines(thePict,dict,topLine,bottomLine);
569
570
571 fprintf(fp,"%d: %d %d %2.6f\n",lineNumber,fontXHeight,ascenderHeight,
572         (float)ascenderHeight/(float)fontXHeight);
573
574 for (shape=startIndex;shape<endIndex; ++shape)
575     StoreOutlinePair(dict,shape,middleLine,fontXHeight,ascenderHeight);
576
577 ++lineNumber;
578 } /* Do another line of text */
579 fclose(fp);
580 }

```

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Aug 21 19:50 1991 baselines.c

```

1  #include <stdio.h>
2  #include <values.h>
3  #include <math.h>
4  #include "boolean.h"
5  #include "pict.h"
6  #include "types.h"
7  #include "lists.h"
8  #include "lines.h"
9  #include "baselines.h"
10
11 extern double sqrt(double);
12 extern int irint(double);
13
14 /*inline*/ int NewReadPixel(UCHAR *base,int width,float x,float y)
15 {
16     int xi;
17     int yi;
18     UCHAR mask;
19
20     xi = irint(x);
21     yi = irint(y);
22     mask = 0x80 >> (xi & 0x7);
23     return *(base+yi*width+(xi>>3)) & mask;
24 }
25
26 void NewCountLine1Bit(Picture pict,int x1,int y1,int x2,int y2,int *black,int *blackEdge)
27 {
28     float x,y;
29     float xinc,yinc;
30     float xupinc,yupinc;
31     float den;
32     int b,be;
33     int width,ucharWidth,height;
34     UCHAR *data;
35
36     width = pict->width;
37     ucharWidth = pict->uchar_width;
38     height = pict->height;
39     data = pict->data;
40
41     den = sqrt((y2-y1)*(y2-y1)+(x2-x1)*(x2-x1));
42     xinc = (x2-x1)/den;
43     yinc = (y2-y1)/den;
44     xupinc = -yinc;
45     yupinc = xinc;
46     x = x1;
47     y = y1;
48
49     b=0;
50     be=0;
51
52     while (x<width&& x>=0&& y<height&& y>=0) {

```

```

53     ++b;
54     if (NewReadPixel(data,ucharWidth,x,y)) {
55         if (!(NewReadPixel(data,ucharWidth,x+xupinc,y+yupinc) &&
56             NewReadPixel(data,ucharWidth,x-xupinc,y-yupinc)))
57             ++be;
58     }
59     x += xinc;
60     y += yinc;
61
62 }
63 *black = b;
64 *blackEdge = be;
65 }
66
67
68 #define MIN_BLACK 5
69 float NewCountLine(Picture pict,int x1,int y1,int x2,int y2)
70 {
71     int black,blackEdge;
72     black = 0;
73     blackEdge = 0;
74     NewCountLine1Bit(pict,x1,y1,x2,y2,&black,&blackEdge);
75     NewCountLine1Bit(pict,x1,y1,x1-(x2-x1),y1-(y2-y1),&black,&blackEdge);
76     if (black < MIN_BLACK)
77         return 0;
78     else
79         return (float)blackEdge/black;
80 }
81
82 static float x2offset;
83 static float y2offset;
84 static int projectIndex;
85 static float *projection;
86 static int *coorx;
87 static int *coory;
88 BOOLEAN BaseLinePiston(Picture pict, int x, int y, BOOLEAN test, UCHAR color)
89 {
90     if (test) {
91         /* if (!(projectIndex%10))
92             DrawLine(pict,x,y,(int)(x+x2offset),(int)(y+y2offset),0xff); */
93         /* WritePixel(pict,x,y,0xff); */
94         projection[projectIndex] = NewCountLine(pict,x,y,(int)(x+x2offset),
95             (int)(y+y2offset));
96         coorx[projectIndex] = x;
97         coory[projectIndex++] = y;
98         return test;
99     } else
100         return test;
101 }
102
103 static int lastX;
104 static int lastY;
105 BOOLEAN EndPointPiston(Picture pict, int x, int y, BOOLEAN test, UCHAR color)
106 {

```


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```

107     if (test) {
108         lastX = x;
109         lastY = y;
110     }
111     return test;
112 }
113
114 void EndPoints(Picture pict,double angle,int *tx, int *ty,int *bx, int *by)
115 {
116     int xc,yc;
117     int maxLength;
118     float normal;
119     float x2,y2,x3,y3;
120
121     /* Make normal to text point in quadrants I and II */
122     /* Assume 0 <= angle < 2*M_PI */
123     normal = fmod(angle + M_PI/2,2*M_PI);
124     if (normal > M_PI)
125         normal -= M_PI;
126
127     xc = pict->width/2;
128     yc = pict->height/2;
129
130     maxLength = pict->width + pict->height;
131     x2 = xc + maxLength*cos(normal);    /* At bottom of picture */
132     y2 = yc + maxLength*sin(normal);
133     x3 = xc - maxLength*cos(normal);    /* At top of picture */
134     y3 = yc - maxLength*sin(normal);
135
136     LineEngine(pict,xc,yc,(int)x2,(int)y2,0,EndPointPiston);
137     *bx = lastX;
138     *by = lastY;
139     LineEngine(pict,xc,yc,(int)x3,(int)y3,0,EndPointPiston);
140     *tx = lastX;
141     *ty = lastY;
142 }
143
144 double distance(int x1,int y1,int x2,int y2)
145 {
146     return sqrt(((double)((x1-x2)*(x1-x2) + (y1-y2)*(y1-y2)));
147 }
148
149 #define BASE_PERCENTILE 0.20
150 #define MIN_LINE_HEIGHT_FRACTION 0.50
151 List BaseLines(Picture pict,double angle,char *plotFile)
152 #ifdef foo
153 ,int *count,
154         int **returnCoordx, int **returnCoordy)
155 #endif
156 {
157     float *topProjection;
158     int *topCoordx,*topCoordy;
159     int *finalCoordx,*finalCoordy,*finalIndex;
160     int topIndex,bottomIndex;
161     int topCount,botCount,finalCount;

```

```

162     int maxLength;
163     int xc,yc;
164     float x2,y2,x3,y3;
165     float maxValue,lastValue;
166     int i,j;
167     float baseThresh;
168     int topX,topY,bottomX,bottomY;
169     BOOLEAN onTextLine;
170     List xList,yList,result;
171     double totalDistance,averageDistance;
172     FILE *outfile;
173
174     printf("angle = %3.3f\n",angle);
175
176     maxLength = pict->width+pict->height;
177
178     topProjection = (float *)calloc(maxLength,sizeof(float));
179     topCoordx = (int *)calloc(maxLength,sizeof(int));
180     topCoordy = (int *)calloc(maxLength,sizeof(int));
181     finalCoordx = (int *)calloc(maxLength,sizeof(int));
182     finalCoordy = (int *)calloc(maxLength,sizeof(int));
183     finalIndex = (int *)calloc(maxLength,sizeof(int));
184
185     if ((topProjection == NULL)||
186         (topCoordx == NULL)||
187         (topCoordy == NULL)||
188         (finalIndex == NULL)||
189         (finalCoordx == NULL)||
190         (finalCoordy == NULL)) {
191         printf("BaseLines: cannot allocate memory\n");
192         exit(-1);
193     }
194
195     EndPoints(pict,angle,&topX,&topY,&bottomX,&bottomY);
196
197     printf("Main Line: (%d,%d)-(%d,%d)\n",topX,topY,bottomX,bottomY);
198     /* DrawLine(pict,topX,topY,bottomX,bottomY,0xff); */
199
200     x2offset = maxLength*cos(angle);
201     y2offset = maxLength*sin(angle);
202     projectIndex = 0;
203     projection = topProjection;
204     coordx = topCoordx;
205     coordy = topCoordy;
206     LineEngine(pict,topX,topY,bottomX,bottomY,0,BaseLinePiston);
207     topCount = projectIndex;
208
209     maxValue = topProjection[0];
210     for (i=0;i<topCount;+ +i) {
211         if (topProjection[i]>maxValue)
212             maxValue = topProjection[i];
213     }
214
215     baseThresh = maxValue*BASE_PERCENTILE;
216     printf("baseThresh = %3.3f\n",baseThresh);

```

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```

217
218 /* Plot the baseline contour if requested */
219 if (plotFile != NULL) {
220     printf("Opening baselines plot file\n");
221     if ((outfile = fopen(plotFile, "w")) == NULL) {
222         printf("Error opening baseline plot file.\n");
223         exit(-1);
224     }
225     for (i=0; i<topCount; ++i)
226         fprintf(outfile, "%d %f\n", i, topProjection[i]);
227     fprintf(outfile, "\nProjection\n\n");
228     fprintf(outfile,
229         "0 %f\n%d %f\n\nBaseline Threshold\n",
230         baseThresh, topCount, baseThresh);
231 }
232
233 finalCount=0;
234 lastValue = topProjection[topCount-1];
235 onTextLine = FALSE;
236 for (i=1; i<topCount; ++i) {
237     if (onTextLine) {
238         if (lastValue > baseThresh && topProjection[i] <= baseThresh) {
239             finalCoordx[finalCount] = topCoordx[i];
240             finalCoordy[finalCount] = topCoordy[i];
241             finalIndex[finalCount] = i;
242             finalCount++;
243             onTextLine = FALSE;
244         }
245     } else {
246         if (lastValue <= baseThresh && topProjection[i] > baseThresh) {
247             finalCoordx[finalCount] = topCoordx[i];
248             finalCoordy[finalCount] = topCoordy[i];
249             finalIndex[finalCount] = i;
250             finalCount++;
251             onTextLine = TRUE;
252         }
253     }
254
255     lastValue = topProjection[i];
256 }
257 if (finalCount & 1)
258     --finalCount; /* Only take an even number of lines */
259 for (totalDistance=0, i=0, j=0; i<finalCount; i+=2) {
260     topX = finalCoordx[i];
261     topY = finalCoordy[i];
262     bottomX = finalCoordx[i+1];
263     bottomY = finalCoordy[i+1];
264     totalDistance += distance(topX, topY, bottomX, bottomY);
265     j+=2;
266 }
267 averageDistance = totalDistance / (finalCount/2)*MIN_LINE_HEIGHT_FRACTION;
268 for (i=0, j=0; i<finalCount; i+=2) {
269     topX = finalCoordx[i];
270     topY = finalCoordy[i];
271     topIndex = finalIndex[i];

```

```

272     bottomX = finalCoordx[i + 1];
273     bottomY = finalCoordy[i + 1];
274     bottomIndex = finalIndex[i + 1];
275     finalCoordx[j] = topX;
276     finalCoordy[j] = topY;
277     finalIndex[j] = topIndex;
278     finalCoordx[j + 1] = bottomX;
279     finalCoordy[j + 1] = bottomY;
280     finalIndex[j + 1] = bottomIndex;
281     if (distance(topX,topY,bottomX,bottomY)>averageDistance)
282         j += 2;
283     }
284     #ifdef foo
285     *count = j;
286     *returnCoordx = finalCoordx;
287     *returnCoordy = finalCoordy;
288     #endif
289     result = nil;
290     for (i=j-1;i>=0;-i) {
291         push(MakePoint(finalCoordx[i],finalCoordy[i]),result);
292     }
293
294     if (plotFile != NULL) {
295         fprintf(outfile,"\\n0 %f\\n",-baseThresh);
296         for (i=0;i<j;i+=2) {
297             fprintf(outfile,"%d %f\\n%d %f\\n%d %f\\n%d %f\\n",
298                 finalIndex[i],-baseThresh,
299                 finalIndex[i],-2*baseThresh,
300                 finalIndex[i+1],-2*baseThresh,
301                 finalIndex[i+1],-baseThresh);
302         }
303         fprintf(outfile,"\\n\"Baselines\"");
304         fclose(outfile);
305         printf("Done writing baseline plot file.\\n");
306     }
307
308     return result;
309 }
310
311 void DrawBaseLines(Picture pict, List pointList, double angle)
312 #ifdef foo
313 int count,int *coordx,int *coordy,double angle)
314 #endif
315 {
316     int maxLength;
317     float x2,y2,x3,y3;
318     int x,y;
319     Point temp;
320     maxLength = pict->width + pict->height;
321     while (!lendp(pointList)) {
322         temp = pop(pointList);
323         x = temp->x;
324         y = temp->y;
325         x2 = x + maxLength*cos(angle);
326         y2 = y + maxLength*sin(angle);

```

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```
327     x3 = x-maxLength*cos(angle);
328     y3 = y-maxLength*sin(angle);
329     DrawLine(pict,x,y,(int)x2,(int)y2,0xff);
330     DrawLine(pict,x,y,(int)x3,(int)y3,0xff);
331 }
332 }
```

Jul 1 13:44 1991 blobify.c

```

1  #include <stdio.h>
2  #include <math.h>
3  #include "boolean.h"
4  #include "pict.h"
5  #include "blobify.h"
6
7  static UCHAR bitmasks[] = {0x80,0x40,0x20,0x10,0x8,0x4,0x2,0x1};
8
9  Picture Blobify(Picture old,int half_mask_size,double threshold)
10 {
11     Picture new;
12     int x,y;
13     int tval;
14     int left,right,top,bottom;
15     int width;
16     int *counters;
17     int *countptr;
18     int mask_size;
19     UCHAR *xptr,*xyptr;
20     int *leftptr;
21     int *rightptr;
22     UCHAR *topptr;
23     UCHAR *bottomptr;
24     int uchar_width;
25     /* UCHAR bitmask; */
26     int count;
27     int inside;
28     int thold;
29     /* Added the following for speedup hack 1/14/91 */
30     UCHAR bitMask;
31     UCHAR *newCursor;
32     UCHAR newValue;
33     UCHAR topPixels;
34     UCHAR bottomPixels;
35
36
37     mask_size = 2 * half_mask_size + 1;
38     /* uchar_width = ROUND8(old->width) >> 3; */
39     uchar_width = old->uchar_width;
40
41     left = half_mask_size;
42     right = old->width - half_mask_size - 1;
43
44     top = half_mask_size;
45     bottom = old->height - half_mask_size - 1;
46
47
48     tval = floor(4*half_mask_size*half_mask_size*threshold);
49     new = new_pict(old->width,old->height,old->depth);
50
51     counters = (int *)calloc(old->width,sizeof(int));
52

```

Section D

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```

53     width = old->width;
54     countptr = counters;
55     xptr = old->data;
56     bitMask = 0x80;
57     for (x=0;x<width; ++x) {
58         /* bitmask = bitmasks[x%8]; */
59         xptr = xptr;
60         for (count=0,y=0;y<mask_size; ++y) {
61             if (*xptr & bitMask)
62                 ++count;
63             xptr += uchar_width;
64         }
65         *(countptr++) = count;
66         /* if (x%8 == 7)
67            * ++xptr; */
68         if (bitMask == 0x01) {
69             bitMask = 0x80;
70             ++xptr;
71         }
72         else
73             bitMask = bitMask >> 1;
74     }
75
76     for (y=top;y<=bottom; ++y) {
77         countptr = counters;
78         for (inside=0,x=0;x<mask_size; ++x)
79             inside += *countptr++;
80
81         leftptr = counters;
82         rightptr = counters + mask_size;
83         newCursor = new->data+y*uchar_width+(left>>3);
84         bitMask = bitmasks[left%8];
85         newValue = 0;
86         for (x=left;x<=right; ++x) {
87             if (inside>tval)
88                 /* set pixel */
89                 newValue |= bitMask;
90             /* *(new->data+y*uchar_width+(x>>3)) |= bitmasks[x%8]; */
91             if (bitMask == 0x01) {
92                 bitMask = 0x80;
93                 *newCursor++ = newValue;
94                 newValue = 0;
95             }
96             else
97                 bitMask = bitMask >> 1;
98             inside += *rightptr++;
99             inside -= *leftptr++;
100         }
101         if (bitMask != 0x80) {
102             *newCursor = newValue;
103         }
104
105         topptr = old->data+(y-half_mask_size)*uchar_width;
106         bottomptr = topptr + mask_size*uchar_width;
107         countptr = counters;

```

```

108     bitMask = 0x01;
109     for (x=0;x<width; ++x) {
110         /* bitmask = bitmasks[x%8]; */
111         if (bitMask == 0x01) {
112             topPixels = *topptr++;
113             bottomPixels = *bottomptr++;
114             bitMask = 0x80;
115         }
116         else
117             bitMask = bitMask >> 1;
118         if (topPixels & bitMask) {
119             if (!(bottomPixels & bitMask))
120                 --(*countptr);
121         }
122         else if (bottomPixels & bitMask)
123             ++(*countptr);
124
125         ++countptr;
126     }
127 }
128
129 return new;
130 }
131
132 #ifdef foo
133 void main(argc,argv)
134 int argc;
135 char **argv;
136 {
137     char *infile,*outfile;
138     Picture old,new;
139     int half_mask_size;
140     float threshold;
141
142     malloc_debug(2);
143
144     if (argc != 5) {
145         printf("Usage: %s infile outfile half_mask_size threshold\n",argv[0]);
146         exit(0);
147     }
148     infile = argv[1];
149     outfile = argv[2];
150     half_mask_size = atoi(argv[3]);
151     threshold = atof(argv[4]);
152
153     printf("Loading %s...",infile);
154     old = load_pict(infile);
155     new = components(old,half_mask_size,threshold);
156     write_pict(outfile,new);
157
158 }
159 #endif
160

```


Aug 26 18:10 1991 boxes.c

```

1  #include <stdio.h>
2  #include <values.h>
3  #include <math.h>
4  #include "boolean.h"
5  #include "pict.h"
6  #include "types.h"
7  #include "lists.h"
8
9  extern int irint(double);
10
11 #define MAX_QUEUE_SIZE 10000
12 #define BLACK 1
13 #define WHITE 0
14
15 #define ABS(a) ((a) < 0 ? -(a) : (a))
16
17 typedef Point PointArray;
18
19 typedef struct {
20     PointBody ulc,lrc;
21 } MinMaxBox;
22
23 typedef struct {
24     PointBody xwitness,ywitness;
25 } WitnessBox;
26
27 typedef struct {
28     PointArray data;
29     int first,last;
30     int size;
31 } QueueBody,*Queue;
32
33 Queue MakeQueue(size)
34 int size;
35 {
36     Queue q;
37     if ((q=(Queue)calloc(1,sizeof(QueueBody)))==NULL) {
38         printf("Cannot alloc space for queue body\n");
39         exit(0);
40     }
41     if ((q->data=(PointArray)calloc(size,sizeof(PointBody)))==NULL) {
42         printf("Cannot allocate space for queue array\n");
43         exit(0);
44     }
45     q->first=q->last=0;
46     q->size=size;
47     return q;
48 }
49
50 void InsertPoint(x,y,q)
51 int x,y;
52 Queue q;

```

```

53  {
54      q->data[q->last].x=x;
55      q->data[q->last].y=y;
56      q->last=(q->last+1)%q->size;
57      if (q->last==q->first) {
58          printf("Maximum q size exceeded\n");
59          exit(0);
60      }
61  }
62
63  void GetFirst(x,y,q)
64  int *x,*y;
65  Queue q;
66  {
67      if (q->first==q->last) {
68          printf("Error: tried to pop empty queue\n");
69          exit(0);
70      }
71      *x=q->data[q->first].x;
72      *y=q->data[q->first].y;
73      q->first=(q->first+1)%q->size;
74  }
75
76  BOOLEAN Empty(q)
77  Queue q;
78  {
79      return q->first==q->last;
80  }
81
82  void InsertBlackNeighbors(Picture pict,int x,int y,Queue queue)
83  {
84      if (ReadPixel(pict,x+1,y)) {
85          WritePixel(pict,x+1,y,WHITE);
86          InsertPoint(x+1,y,queue);
87      }
88      if (ReadPixel(pict,x-1,y)) {
89          WritePixel(pict,x-1,y,WHITE);
90          InsertPoint(x-1,y,queue);
91      }
92      if (ReadPixel(pict,x,y+1)) {
93          WritePixel(pict,x,y+1,WHITE);
94          InsertPoint(x,y+1,queue);
95      }
96      if (ReadPixel(pict,x,y-1)) {
97          WritePixel(pict,x,y-1,WHITE);
98          InsertPoint(x,y-1,queue);
99      }
100 }
101
102 void PointFromTheta(theta,x,y)
103 float theta;
104 float *x,*y;
105 {
106     *x = cos(theta);
107     *y = sin(theta);

```

```

108  }
109
110  void Normal(x,y,nx,ny)
111  float x,y;
112  float *nx,*ny;
113  {
114      *nx = -y;
115      *ny = x;
116  }
117
118  int DotFl(fx,fy,ix,iy)
119  float fx,fy;
120  int ix,iy;
121  {
122      return irint(fx*ix+fy*iy);
123  }
124
125  static float pox,poy,px,py;
126
127  void MinMax(boundingBox,oldFrameBox,px,py)
128  MinMaxBox *boundingBox;
129  WitnessBox *oldFrameBox;
130  int px,py;
131  {
132      /* IGNORE THETA FOR THE TIME BEING */
133      if (boundingBox->lrc.x < DotFl(pox,poy,px,py)) {
134          boundingBox->lrc.x = DotFl(pox,poy,px,py);
135      }
136      if (boundingBox->lrc.y < DotFl(pnx,pny,px,py)) {
137          boundingBox->lrc.y = DotFl(pnx,pny,px,py);
138      }
139      if (boundingBox->ulc.x > DotFl(pox,poy,px,py)) {
140          boundingBox->ulc.x = DotFl(pox,poy,px,py);
141          oldFrameBox->xwitness.x = px;
142          oldFrameBox->xwitness.y = py;
143      }
144      if (boundingBox->ulc.y > DotFl(pnx,pny,px,py)) {
145          boundingBox->ulc.y = DotFl(pnx,pny,px,py);
146          oldFrameBox->ywitness.x = px;
147          oldFrameBox->ywitness.y = py;
148      }
149  }
150
151  /* Set the pixels on the border of the image to the color WHITE so that
152  * the paint routine need never worry about going off the edge of the
153  * image. */
154  void FramePicture(pict)
155  Picture pict;
156  {
157      int i;
158      for (i=0;i<pict->height;+ +i) {
159          WritePixel(pict,0,i,WHITE);
160          WritePixel(pict,pict->width-1,i,WHITE);
161      }
162      for (i=0;i<pict->width;+ +i) {

```

```

163     WritePixel(pict,i,0,WHITE);
164     WritePixel(pict,i,pict->height-1,WHITE);
165 }
166 }
167
168 /*
169  * Given as input a thresholded image, find the borders of the connected
170  * components. Assumes image is thresholded to 0 and 1.
171  */
172 void PaintComponent(pict,x,y,queue,boundingBox,oldFrameBox)
173 Picture pict;
174 int x,y;
175 Queue queue;
176 MinMaxBox *boundingBox;
177 WitnessBox *oldFrameBox;
178 {
179     boundingBox->ulc.x = boundingBox->lrc.x = DotFl(pox,poy,x,y);
180     boundingBox->ulc.y = boundingBox->lrc.y = DotFl(pnx,pny,x,y);
181     oldFrameBox->xwitness.x = oldFrameBox->ywitness.x = x;
182     oldFrameBox->xwitness.y = oldFrameBox->ywitness.y = y;
183
184     InsertPoint(x,y,queue);
185     WritePixel(pict,x,y,WHITE);
186     /* printf("Queue status: %s\n", (Empty(queue))?"empty":"not empty"); */
187     while (!Empty(queue)) {
188         GetFirst(&x,&y,queue);
189         MinMax(boundingBox,oldFrameBox,x,y);
190         InsertBlackNeighbors(pict,x,y,queue);
191     }
192 }
193
194 int iabs(int x)
195 {
196     if (x<0)
197         return -x;
198     else
199         return x;
200 }
201
202 BOOLEAN PointInBounds(Picture pict,int x,int y)
203 {
204     return x>=0 && x<pict->width && y>=0 && y<pict->height;
205 }
206
207
208 BOOLEAN BoxInBounds(Picture pict,int x, int y, int width, int height,
209                     double angle)
210 {
211     int rightX,rightY,downX,downY;
212     rightX = width*cos(angle);
213     rightY = width*sin(angle);
214     downX = height*cos(angle + M_PI/2);
215     downY = height*sin(angle + M_PI/2);
216     return (PointInBounds(pict,x,y) &&
217             PointInBounds(pict,x+rightX,y+rightY) &&

```

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```

218         PointInBounds(pict,x+rightX+downX,y+rightY+downY) &&
219         PointInBounds(pict,x+downX,y+downY));
220     }
221
222     void GetCorner(WitnessBox *box,int *ulcx,int *ulcy)
223     {
224         double c2;
225         c2 = (-pny*(box->ywitness.x-box->xwitness.x) +
226             pnx*(box->ywitness.y-box->xwitness.y) ) /
227             (pox*pny - pnx*poy);
228         *ulcx = c2*pox + box->ywitness.x;
229         *ulcy = c2*poy + box->ywitness.y;
230     }
231
232     List FindBorders(Picture pict,double theta)
233     {
234         int x,y;
235         int ulcx,ulcy;
236         Queue queue;
237         MinMaxBox boundingBox;
238         WitnessBox oldFrameBox;
239         List boxList;
240         int width,height;
241
242         queue = MakeQueue(MAX_QUEUE_SIZE);
243
244         PointFromTheta(theta,&pox,&poy);
245         Normal(pox,poy,&pnx,&pny);
246
247         printf("Framing picture\n");
248         FramePicture(pict);          /* Put a "visited" color border
249                                     * around the image */
250         boxList = nil;
251         for (y=1;y<pict->height-1; ++y)
252             for (x=1;x<pict->width-1; ++x)
253                 if (ReadPixel(pict,x,y)) {
254                     /* printf("Found component at (%d,%d)\n",x,y); */
255                     PaintComponent(pict,x,y,queue,&boundingBox,&oldFrameBox);
256                     /* printf("Making box: %d %d %d %d\n",
257                             oldFrameBox.ulc.x,
258                             oldFrameBox.ulc.y,
259                             oldFrameBox.lrc.x,
260                             oldFrameBox.lrc.y);
261                     */
262                     GetCorner(&oldFrameBox,&ulcx,&ulcy);
263                     width = boundingBox.lrc.x-boundingBox.ulc.x;
264                     height = boundingBox.lrc.y-boundingBox.ulc.y;
265                     /* if (fabs(height)>10) */
266                     if (BoxInBounds(pict,ulcx,ulcy,
267                                     width,height,theta))
268                         push(MakeBox(ulcx,ulcy,
269                                     width,height,theta),
270                             boxList);
271                 }
272         printf("Found %d boxes completely on the page\n",ListLength(boxList));

```

```

273     return boxList;
274 }
275
276 void DrawBox(Picture pict,Box box)
277 {
278     int rightX,rightY,downX,downY;
279     rightX = box->width*cos(box->angle);
280     rightY = box->width*sin(box->angle);
281     downX = box->height*cos(box->angle+M_PI/2);
282     downY = box->height*sin(box->angle+M_PI/2);
283     /* printf("DrawBox: %d %d %d %d\n",box->x,box->y,box->width<,box->height); */
284     DrawLine(pict,box->x,box->y,box->x+rightX,box->y+rightY,0xff);
285     DrawLine(pict,box->x+rightX,box->y+rightY,
286             box->x+rightX+downX,box->y+rightY+downY,0xff);
287     DrawLine(pict,box->x+rightX+downX,box->y+rightY+downY,
288             box->x+downX,box->y+downY,0xff);
289     DrawLine(pict,box->x+downX,box->y+downY,box->x,box->y,0xff);
290 }
291
292 void DrawColorBox(Picture pict,Box box,int color)
293 {
294     int rightX,rightY,downX,downY;
295     rightX = box->width*cos(box->angle);
296     rightY = box->width*sin(box->angle);
297     downX = box->height*cos(box->angle+M_PI/2);
298     downY = box->height*sin(box->angle+M_PI/2);
299     /* printf("DrawBox: %d %d %d %d\n",box->x,box->y,box->width<,box->height); */
300     DrawLine(pict,box->x,box->y,box->x+rightX,box->y+rightY,color);
301     DrawLine(pict,box->x+rightX,box->y+rightY,
302             box->x+rightX+downX,box->y+rightY+downY,color);
303     DrawLine(pict,box->x+rightX+downX,box->y+rightY+downY,
304             box->x+downX,box->y+downY,color);
305     DrawLine(pict,box->x+downX,box->y+downY,box->x,box->y,color);
306 }
307
308
309 void DrawBoxList(Picture pict,List boxList)
310 {
311     while (!endp(boxList)) {
312         DrawBox(pict,(Box)pop(boxList));
313     }
314 }
315
316
317 #ifdef TRYMAIN
318 /* WARNING - be sure to replace the height check in FindBorders */
319 #endif
320 void main(argc,argv)
321 int argc;
322 char **argv;
323 {
324     char *infileName,*outfileName;
325     List boxList;
326     int width,height;
327     float theta;

```

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```
328     Picture pict,finalPict;
329     FILE *outfile;
330
331     if (argc != 4) {
332         printf("Usage: %s infile outfile page_orientation\n",argv[0]);
333         exit(0);
334     }
335     inFileName = argv[1];
336     outFileName = argv[2];
337     theta = atof(argv[3]);
338
339     printf("Loading %s...",inFileName);
340     pict = load_pict(inFileName);
341
342     printf("\nFinding boxes.\n");
343
344     finalPict = new_pict(pict->width,pict->height,pict->depth);
345     /* CopyPicture(finalPict,pict); */
346     boxList = FindBorders(pict,theta);
347
348     DrawBoxList(finalPict,boxList);
349     write_pict(outFileName,finalPict);
350 }
```

Jan 16 15:52 1991 dict.c

```

1  #include <stdio.h>
2  #include "boolean.h"
3  #include "types.h"
4  #include "error.h"
5  #include "pict.h"
6  #include "dict.h"
7
8  void WriteOutlinePair(OutlinePair o, FILE *fp)
9  {
10     fwrite(o->box,sizeof(BoxBody),1,fp);
11     fwrite(&(o->blackoutHeight),sizeof(float),1,fp);
12     fwrite(&(o->numberOfLegs),sizeof(int),1,fp);
13     fwrite(&(o->offset),sizeof(int),1,fp);
14     fwrite(&(o->width),sizeof(int),1,fp);
15
16     fwrite(o->x,sizeof(float),o->numberOfLegs,fp);
17     fwrite(o->top,sizeof(float),o->numberOfLegs,fp);
18     fwrite(o->bottom,sizeof(float),o->numberOfLegs,fp);
19 }
20
21 void WriteDictionary(Dictionary dict, char *filename)
22 {
23     FILE *fp;
24     int temp;
25     int i;
26     if ((fp=fopen(filename,"w"))==NULL)
27         DoError("WriteDictionary: Error opening output file.\n",NULL);
28     temp = 1234567;
29     fwrite(&temp,sizeof(int),1,fp);
30     fwrite(&(dict->numberOfEntries),sizeof(int),1,fp);
31
32     if (dict->infoString == NULL) {
33         temp = 0;
34         fwrite(&temp,sizeof(int),1,fp);
35     }
36     else{
37         temp = strlen(dict->infoString)+1;
38         fwrite(&temp,sizeof(int),1,fp);
39         fwrite(dict->infoString,sizeof(char),temp,fp);
40     }
41
42     for (i=0;i<dict->numberOfEntries; ++i)
43         WriteOutlinePair(*(dict->outlines+i),fp);
44     fclose(fp);
45 }
46
47
48 /* Reads a Box from a binary stream. the type Box is defined in box.h */
49 Box ReadBox(FILE *fp)
50 {
51     Box temp;
52     temp = (Box)calloc(1,sizeof(BoxBody));

```


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```

53     if (temp == NULL)
54         DoError("ReadBox: cannot allocate space\n",NULL);
55     if (fread(temp,sizeof(BoxBody),1,fp) != 1)
56         DoError("ReadBox: error reading bounding box\n",NULL);
57     return temp;
58 }
59
60 /* Reads an OutlinePair from a binary stream. The format of an OutlinePair
61  * follows:
62  *   BoxBody - shape bounding box
63  *   float   - blackout bar height
64  *   int      - number of legs in the contour
65  *   int      - x coordinate of left edge of contour
66  *   int      - width in pixels of edge contour
67  *   float[numberOfLegs] - x coordinates of contours
68  *   float[numberOfLegs] - y coordinates of top contour
69  *   float[numberOfLegs] - y coordinates of bottom contour
70  */
71 OutlinePair ReadOutlinePair(FILE *fp)
72 {
73     OutlinePair temp;
74     temp = (OutlinePair) calloc(1,sizeof(OutlinePairBody));
75     if (temp == NULL)
76         DoError("ReadOutlinePair: cannot allocate space\n",NULL);
77     temp->box = ReadBox(fp);
78
79     if (fread(&(temp->blackoutHeight),sizeof(float),1,fp) != 1)
80         DoError("ReadOutlinePair: error reading blackoutHeight\n",NULL);
81
82     if (fread(&(temp->numberOfLegs),sizeof(int),1,fp) != 1)
83         DoError("ReadOutlinePair: error reading length\n",NULL);
84
85     if (fread(&(temp->offset),sizeof(int),1,fp) != 1)
86         DoError("ReadOutlinePair: error reading offset\n",NULL);
87     if (fread(&(temp->width),sizeof(int),1,fp) != 1)
88         DoError("ReadOutlinePair: error reading width\n",NULL);
89
90     temp->x = (float *) calloc(temp->numberOfLegs,sizeof(float));
91     if (temp->x == NULL)
92         DoError("ReadOutlinePair: cannot allocate space\n",NULL);
93     if (fread(temp->x,
94             sizeof(float),temp->numberOfLegs,fp) != temp->numberOfLegs)
95         DoError("ReadOutlinePair: error reading x coords\n",NULL);
96
97     temp->top = (float *) calloc(temp->numberOfLegs,sizeof(float));
98     if (temp->top == NULL)
99         DoError("ReadOutlinePair: cannot allocate space\n",NULL);
100    if (fread(temp->top,sizeof(float),
101            temp->numberOfLegs,fp) != temp->numberOfLegs)
102        DoError("ReadOutlinePair: error reading topY coords\n",NULL);
103
104    temp->bottom = (float *) calloc(temp->numberOfLegs,sizeof(float));
105    if (temp->bottom == NULL)
106        DoError("ReadOutlinePair: cannot allocate space\n",NULL);
107    if (fread(temp->bottom,

```

```

108         sizeof(float),temp->numberOfLegs,fp)!=temp->numberOfLegs)
109     DoError("ReadOutlinePair: error reading bottomY coords\n",NULL);
110
111     return temp;
112 }
113
114 /* Create a new Dictionary structure with space allocated for the
115  * entries. */
116 Dictionary NewDict(int numberOfEntries)
117 {
118     Dictionary temp;
119     temp = (Dictionary)calloc(1,sizeof(DictionaryBody));
120     if (temp == NULL)
121         DoError("NewDict: cannot allocate space\n",NULL);
122     temp->numberOfEntries = numberOfEntries;
123     temp->infoString = NULL;
124     temp->rawOutlines = (RawOutlinePair *)calloc(numberOfEntries,
125                                                  sizeof(RawOutlinePair));
126     temp->outlines = (OutlinePair *)calloc(numberOfEntries,
127                                           sizeof(OutlinePair));
128     if ((temp->outlines == NULL)||((temp->rawOutlines == NULL))
129         DoError("NewDict: cannot allocate space\n",NULL);
130     return temp;
131 }
132
133 /* Read a dictionary from a binary format file. The file organization
134  * follows:
135  * int - number of entries in the dictionary
136  * OutlinePair[numberOfEntries] - outlines of each shape in the dictionary
137  * When a dictionary is read in, the shapes are sorted such that they fall
138  * in the order of words on textlines. */
139 Dictionary ReadDictionary(char *filename)
140 {
141     FILE *fp;
142     Dictionary dict;
143     int i;
144     int temp;
145     int infoStringLength;
146     int numberOfEntries;
147     int magicNumber;
148
149     if ((fp=fopen(filename,"r"))==NULL)
150         DoError("Error opening input file\n",NULL);
151
152     if (fread(&magicNumber,sizeof(int),1,fp)!=1)
153         DoError("Error reading dictionary\n",NULL);
154     if (magicNumber != 1234567)
155         DoError("ReadDictionary: input file %s is not a dictionary file.\n",
156               filename);
157
158     if (fread(&numberOfEntries,sizeof(int),1,fp)!=1)
159         DoError("Error reading dictionary\n",NULL);
160     dict = NewDict(numberOfEntries);
161
162     if (fread(&infoStringLength,sizeof(int),1,fp)!=1)

```

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```

163     DoError("Error reading dictionary\n",NULL);
164     if (infoStringLength) {
165         if ((dict->infoString = (char *)calloc(infoStringLength,sizeof(char))) ==
166             NULL)
167             DoError("ReadDictionary: cannot allocate space for info string.\n",NULL);
168         fread(dict->infoString,infoStringLength,sizeof(char),fp);
169         *(dict->infoString+infoStringLength-1) = '\0'; /* Set last char to 0 just in case */
170     }
171
172     for (i=0;i<numberOfEntries; ++i)
173         *(dict->outlines+i) = ReadOutlinePair(fp);
174     fclose(fp);
175     return dict;
176 }
177
178 char *ArgListToString(int argc, char **argv)
179 {
180     int i;
181     int totalLength;
182     char *theString;
183     char *destCursor,*srcCursor;
184
185     for (i=0,totalLength=0;i<argc; ++i)
186         totalLength += strlen(argv[i]) + 1; /* Room for each arg and one space */
187     totalLength ++; /* Room for the EOS character */
188
189     if ((theString = (char *)calloc(totalLength,sizeof(char))) == NULL)
190         DoError("ArgListToString: cannot allocate space.\n",NULL);
191
192     for (i=0,destCursor=theString;i<argc; ++i) {
193         srcCursor = argv[i];
194         while (*srcCursor != '\0')
195             *destCursor++ = *srcCursor++;
196         *destCursor++ = ' ';
197     }
198     *destCursor = '\0';
199
200     return theString;
201 }

```

Section D

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Jan 11 17:06 1991 dmain.c

```
1  #include <stdio.h>
2  #include <math.h>
3  #include <values.h>
4  #include "boolean.h"
5  #include "types.h"
6  #include "pict.h"
7  #include "diff.h"
8
9
10 void main(int argc, char **argv)
11 {
12     Picture pict;
13     char *infile1, *infile2, *outfile;
14
15     if (argc != 4) {
16         printf("Usage:\n");
17         printf(" %s infile1 infile2 outfile\n", argv[0]);
18         exit(-1);
19     }
20
21     infile1 = argv[1];
22     infile2 = argv[2];
23     outfile = argv[3];
24     pict = CompareDictionaries(infile1, infile2);
25     WritePictureAsAscii(pict, outfile);
26 }
```

Jun 21 15:54 1991 fft.c

```

1  /* Copyright 1991 by Michael Hopcroft.
2  * Right is hereby granted to Xerox Corporation to make use of this
3  * code free of charge. */
4  #include <stdio.h>
5  #include <math.h>
6  #include "fft.h"
7
8  /* Applies bit reversal permutation matrix to array a. length must be a power
9  * of 2. */
10 void BitReverse(float *a, int n)
11 {
12     int i,j,k;
13     float temp;
14
15     j=1;
16     for(i=1;i<n; ++i) {
17         if (i<j) {
18             temp = a[i-1];
19             a[i-1] = a[j-1];
20             a[j-1] = temp;
21         }
22         k=n/2;
23         while (k<j) {
24             j = j-k;
25             k = k/2;
26         }
27         j = j+k;
28     }
29 }
30
31 #define TWOPI (M_PI*2)
32
33 void fft(float *real,float *imag,int logn,int mode)
34 {
35     int n;
36     int j,top,i,id,bottom;
37     int stage,subpartLength;
38     float tempr,tempi,temp2r,temp2i,ar,ai,wr,wi,angle;
39
40     n = irint(exp2((double)logn));
41
42     for (stage=1, subpartLength = n;
43         stage<= logn;
44         ++stage, subpartLength/=2) {
45         angle = TWOPI/subpartLength;
46         ar = 1.0;
47         ai = 0.0;
48         if (mode == REVERSE) {
49             wr = cos(angle);
50             wi = sin(angle);
51         } else {
52             wr = cos(angle);

```

```

53     wi = -sin(angle);
54 }
55 for (j=0;j<subpartLength/2; ++j) { /* for each offset in a part */
56     for (top=j; top<n; top+=subpartLength) { /* for each part */
57         bottom = top+subpartLength/2;
58         tempr = real[bottom]; /* temp = x[id] */
59         tempi = imag[bottom];
60         real[bottom] = real[top]-real[bottom]; /* x[id] = x[i] - x[id] */
61         imag[bottom] = imag[top]-imag[bottom];
62         temp2r = real[bottom]*ar-imag[bottom]*ai; /* temp2 = x[id]*a */
63         temp2i = real[bottom]*ai+imag[bottom]*ar;
64         real[bottom] = temp2r; /* x[id] = temp2 */
65         imag[bottom] = temp2i;
66         real[top] += tempr; /* x[i] += temp */
67         imag[top] += tempi;
68     }
69     temp2r = ar*wr-ai*wi; /* a * = w */
70     temp2i = ai*wr+ar*wi;
71     ar = temp2r;
72     ai = temp2i;
73 }
74 }
75 BitReverse(real,n);
76 BitReverse(imag,n);
77
78 #ifdef foo
79     if (mode == MAGNITUDE)
80         for (i=0;i<n; ++i)
81             real[i] = sqrt(real[i]*real[i]+imag[i]*imag[i]);
82 #endif
83
84     if (mode == MAGNITUDE)
85         for (i=0;i<n; ++i)
86             real[i] = sqrt(real[i]*real[i]+imag[i]*imag[i]);
87 }
88
89 #ifdef TRYMAIN
90 void main(int argc, char **argv)
91 {
92     #define POWER 8
93     #define LENGTH 256
94     float real[LENGTH];
95     float imag[LENGTH];
96     int i;
97     #ifdef foo
98         for (i=0;i<LENGTH; ++i){
99             if (i<LENGTH/2)
100                 real[i] = 1.0;
101             else
102                 real[i] = 0.0;
103             imag[i] = 0.0;
104         }
105     #endif
106
107     for (i=0;i<LENGTH; ++i) {

```

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```
108     real[i] = sin(8*TWOPI*i/(LENGTH-1));
109     imag[i] = 0.0;
110 }
111 fft(real,imag,POWER,MAGNITUDE);
112 for (i=0;i<LENGTH; ++i)
113     printf("%d %f\n",i,real[i]);
114 }
115 #endif
116
```

Aug 15 21:19 1991 fontNorm.c

```

1  #include <stdio.h>
2  #include <math.h>
3  #include "boolean.h"
4  #include "types.h"
5  #include "error.h"
6  #include "pict.h"
7  #include "dict.h"
8  #include "fontNorm.h"
9
10
11  extern double ceil(double);
12  extern int irint(double);
13
14
15  #define UP 0
16  #define DOWN 1
17  typedef int Direction;
18
19  extern Picture thePict;
20
21  void StoreRawOutlinePair(Dictionary dict, Int dictEntry,
22                          Box box, int *bothX, int *topY, int *baseY,
23                          int numberOfLegs)
24  {
25      RawOutlinePair temp;
26      int i;
27      int *xCursor, *topCursor, *bottomCursor;
28
29      temp = (RawOutlinePair) calloc(1, sizeof(RawOutlinePairBody));
30      if (temp == NULL)
31          DoError("StoreRawOutlinePair: cannot allocate space\n", NULL);
32
33      temp->box = box;
34      temp->numberOfLegs = numberOfLegs;
35
36      temp->x = (int *) calloc(temp->numberOfLegs, sizeof(int));
37      temp->top = (int *) calloc(temp->numberOfLegs, sizeof(int));
38      temp->bottom = (int *) calloc(temp->numberOfLegs, sizeof(int));
39      if ((temp->x == NULL) ||
40          (temp->top == NULL) ||
41          (temp->bottom == NULL))
42          DoError("StoreRawOutlinePair: cannot allocate space\n", NULL);
43
44      xCursor = temp->x;
45      topCursor = temp->top;
46      bottomCursor = temp->bottom;
47
48      for (i=0; i<numberOfLegs; ++i) {
49          *xCursor++ = *bothX++;
50          *topCursor++ = *topY++;
51          *bottomCursor++ = *baseY++;
52      }

```



```

53     *(dict->rawOutlines+dictEntry) = temp;
54 }
55
56 int RawOutlineWidth(RawOutlinePair a,int middleLine)
57 {
58     int i,numberOfLegs,right,left;
59     int *topCursor,*bottomCursor;
60     int topValue,bottomValue;
61
62     numberOfLegs = a->numberOfLegs;
63
64     topCursor = a->top;
65     bottomCursor = a->bottom;
66     for (i=0;i<numberOfLegs; ++i) {
67         topValue = *topCursor++;
68         bottomValue = *bottomCursor++;
69
70         if (topValue != HIT_THE_BOX) {
71             topValue = middleLine - topValue;
72             if (topValue<0)
73                 topValue = 0;
74         }
75         else
76             topValue = 0;
77
78         if (bottomValue != HIT_THE_BOX) {
79             bottomValue = bottomValue - middleLine;
80             if (bottomValue < 0)
81                 bottomValue = 0;
82         }
83         else
84             bottomValue = 0;
85
86         if ((bottomValue != 0)|| (topValue != 0))
87             break;
88     }
89     left = i;
90
91     topCursor = a->top+numberOfLegs-1;
92     bottomCursor = a->bottom+numberOfLegs-1;
93     for (i=numberOfLegs-1;i>=0;--i) {
94         topValue = *topCursor--;
95         bottomValue = *bottomCursor--;
96
97         if (topValue != HIT_THE_BOX) {
98             topValue = middleLine - topValue;
99             if (topValue<0)
100                 topValue = 0;
101         }
102         else
103             topValue = 0;
104
105         if (bottomValue != HIT_THE_BOX) {
106             bottomValue = bottomValue - middleLine;
107             if (bottomValue < 0)

```

```

108         bottomValue = 0;
109     }
110     else bottomValue = 0;
111
112     if ((topValue != 0) || (bottomValue != 0))
113         break;
114 }
115 right = i + 1;
116
117 return right-left;
118 }
119
120 void ResampleOutlinePair(OutlinePair a, float newToOldFactor)
121 /* Resample an outline pair using linear interpolation. */
122 {
123     int newWidth, oldWidth, i;
124     int oldLeft, oldRight;
125     float oldCenter;
126     float *newX, *newTop, *newBottom;
127     float *xCursor, *topCursor, *bottomCursor;
128
129     oldWidth = a->numberOfLegs;
130     newWidth = irint(newToOldFactor*oldWidth);
131
132     newX = (float *)calloc(newWidth, sizeof(float));
133     newTop = (float *)calloc(newWidth, sizeof(float));
134     newBottom = (float *)calloc(newWidth, sizeof(float));
135     if ((newX == NULL) || (newTop == NULL) || (newBottom == NULL))
136         DoError("ResampleOutlinePair: cannot allocate space.\n", NULL);
137
138     xCursor = newX;
139     topCursor = newTop;
140     bottomCursor = newBottom;
141
142     for (i = 0; i < newWidth; ++i) {
143         oldCenter = i/(float)newWidth*(float)oldWidth;
144         oldLeft = irint(floor(oldCenter));
145         oldRight = irint(ceil(oldCenter));
146         if (oldLeft == oldRight) {
147             *xCursor++ = *(a->x + oldLeft);
148             *topCursor++ = *(a->top + oldLeft);
149             *bottomCursor++ = *(a->bottom + oldLeft);
150         }
151         else {
152             float slope;
153             slope = *(a->x + oldRight) - *(a->x + oldLeft);
154             *xCursor++ = *(a->x + oldLeft) + (oldCenter - oldLeft)*slope;
155             slope = *(a->top + oldRight) - *(a->top + oldLeft);
156             *topCursor++ = *(a->top + oldLeft) + (oldCenter - oldLeft)*slope;
157             slope = *(a->bottom + oldRight) - *(a->bottom + oldLeft);
158             *bottomCursor++ = *(a->bottom + oldLeft) + (oldCenter - oldLeft)*slope;
159         }
160     }
161
162     free(a->x);

```

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```

163     free(a->top);
164     free(a->bottom);
165
166     a->x = newX;
167     a->top = newTop;
168     a->bottom = newBottom;
169     a->numberOfLegs = newWidth;
170 }
171
172 void StoreOutlinePair(Dictionary dict, int dictEntry,
173                      int middleLine, int fontXHeight,
174                      int ascenderHeight, NormalizationDescriptor *nd)
175 /* This routine normalizes the raw outline pair stored in dict at dictEntry using the following
176  * operations:
177  * 1) For the top contour, shift so that the middle line is at y=0 and negate so that the
178  *    higher points are greater than 0. For the bottom, shift so that middle line is at y=0,
179  *    but don't flip. Thus, lower points have y coordinates greater than 0.
180  *    Consider points whose value is HIT_THE_BOX to be at y=0. These correspond to gaps
181  *    between the letters.
182  * 2) Compress top and bottom y coordinates by 1/fontXHeight so that the coordinates at
183  *    the
184  *    distance of the fontXHeight have value 1. Note that 1 is an arbitrary number. It is
185  *    unlikely that a signal will have parts that are the x height above the center line
186  *    anyway.
187  *    FOR TOP CONTOUR,
188  *    IF HEIGHT IS GREATER THAN XHEIGHT, SCALE DIFFERENCE BY 1.5/ASCENDER_HEIGHT.
189  *    ELSE SCALE DIFFERENCE BY 1/XHEIGHT.
190  *    FOR BOTTOM CONTOUR,
191  *    SCALE BY 1.5/ASCENDER_HEIGHT.
192  * 3) Compress the x coordinates by the same factor as in step 2. Note that this does not
193  *    actually resample the contour. NOW DO THIS WITH RESAMPLE. USE SCALE FACTOR OF
194  *    20/XHEIGHT.
195  * 4) Remove left and right ends of the contour that have y values of zero. This is so the
196  *    contour starts where the word starts, rather than at the edge of its bounding box.
197  * 5) Resample the contour to stretch by firstFontXwidth/fontxWidth. KILL THIS
198  *    OPERATION.
199  */
200 {
201     RawOutlinePair raw;
202     OutlinePair temp;
203     int i, numberOfLegs;
204     int y;
205     int offset;
206     int *xSCursor, *topSCursor, *bottomSCursor;
207     float *xDCursor, *topDCursor, *bottomDCursor;
208     float *xCursor, *topCursor, *bottomCursor;
209     int left, right;
210     float foffset;
211     float ascenderFactor, xHeightFactor, widthFactor;
212
213     raw = *(dict->rawOutlines + dictEntry);
214
215     temp = (OutlinePair)calloc(1, sizeof(OutlinePairBody));
216     if (temp == NULL)
217         DoError("StoreOutlinePair: cannot allocate space\n", NULL);

```

```

216
217     temp->x = (float *)calloc(raw->numberOfLegs,sizeof(float));
218     temp->top = (float *)calloc(raw->numberOfLegs,sizeof(float));
219     temp->bottom = (float *)calloc(raw->numberOfLegs,sizeof(float));
220     if ((temp->x == NULL) ||
221         (temp->top == NULL) ||
222         (temp->bottom == NULL))
223         DoError("StoreOutlinePair: cannot allocate space\n",NULL);
224
225     temp->box = raw->box;
226     temp->blackoutHeight = 0;
227     temp->numberOfLegs = raw->numberOfLegs;
228     offset = temp->offset = *(raw->x);
229     temp->width = *(raw->x+raw->numberOfLegs-1) - temp->offset;
230
231     xDCursor = temp->x;
232     topDCursor = temp->top;
233     bottomDCursor = temp->bottom;
234     xSCursor = raw->x;
235     topSCursor = raw->top;
236     bottomSCursor = raw->bottom;
237
238     ascenderFactor = 1.5/ascenderHeight;
239     xHeightFactor = 1.0/fontXHeight;
240     widthFactor = 20.0/fontXHeight;
241     if (nd->noXHeightNormalize) {
242         xHeightFactor = 1.0;
243         ascenderFactor = 1.0;
244     }
245     if (nd->noAscenderNormalize)
246         ascenderFactor = xHeightFactor;
247
248     numberOfLegs = raw->numberOfLegs;
249     for (i=0; i<numberOfLegs; ++i) {
250         if (*topSCursor == HIT_THE_BOX) {
251             y = 0;
252             topSCursor++;
253         }
254         else {
255             y = middleLine - *topSCursor++;
256             if (y<0)
257                 y = 0;
258         }
259         if (y>fontXHeight/2) {
260             float temp1 = (float)y * ascenderFactor;
261             float temp2 = (float)fontXHeight/2 * xHeightFactor;
262             if (temp1<temp2)
263                 *topDCursor++ = temp2;
264             else
265                 *topDCursor++ = temp1;
266         }
267         *topDCursor++ = (float)y * ascenderFactor;
268     }
269     else
270

```

```

271     *topDCursor++ = (float)y * xHeightFactor;
272
273     if (*bottomSCursor == HIT_THE_BOX) {
274         y = 0;
275         bottomSCursor++;
276     }
277     else {
278         y = *bottomSCursor++ - middleLine;
279         if (y < 0)
280             y = 0;
281     }
282     if (y < fontXHeight/2)
283         *bottomDCursor++ = (float)y * xHeightFactor;
284     else {
285         float temp1 = (float)y * ascenderFactor;
286         float temp2 = (float)fontXHeight/2 * xHeightFactor;
287         if (temp1 < temp2)
288             *bottomDCursor++ = temp2;
289         else
290             *bottomDCursor++ = temp1;
291     /* *bottomDCursor++ = (float)y * ascenderFactor; */
292     }
293 }
294
295 /* Now try to remove parts of the contour on to the left and right of the
296 * word shape that are at height 0 */
297
298 /* Find left edge */
299 topDCursor = temp->top;
300 bottomDCursor = temp->bottom;
301 for (i=0; i<numberOfLegs; ++i) {
302     if ((*topDCursor++ != 0) || (*bottomDCursor++ != 0))
303         break;
304 }
305 left = i;
306
307 /* Find right edge */
308 topDCursor = temp->top + numberOfLegs-1;
309 bottomDCursor = temp->bottom + numberOfLegs-1;
310 for (i=numberOfLegs-1; i>=0; --i) {
311     if ((*topDCursor-- != 0) || (*bottomDCursor-- != 0))
312         break;
313 }
314 right = i+1;
315
316 /* Clip the ends of the contour at left and right */
317 xDCursor = temp->x;
318 topDCursor = temp->top;
319 bottomDCursor = temp->bottom;
320 xCursor = temp->x+left;
321 topCursor = temp->top+left;
322 bottomCursor = temp->bottom+left;
323 foffset = *xSCursor;
324 for (i=left; i<right; ++i) {
325     *xDCursor++ = *xCursor++ - foffset;

```

```

326     *topDCursor++ = *topCursor++;
327     *bottomDCursor++ = *bottomCursor++;
328 }
329 temp->numberOfLegs = right-left;
330
331 *(dict->outlines+dictEntry) = temp;
332 ResampleOutlinePair(*(dict->outlines+dictEntry),widthFactor);
333 }
334
335 static int lineSpacing;
336 int OrderOutlinePair(OutlinePair *o1,OutlinePair *o2)
337 {
338     int yDistance;
339     int xDistance;
340     yDistance = (*o1)->box->pageY - (*o2)->box->pageY;
341     if (yDistance < lineSpacing && yDistance > -lineSpacing) {
342         xDistance = (*o1)->box->pageX - (*o2)->box->pageX;
343         return xDistance;
344     }
345     return yDistance;
346 }
347
348 void SortDictionary(Dictionary dict)
349 {
350     lineSpacing = 20;
351     qsort(dict->rawOutlines,dict->numberOfEntries,sizeof(RawOutlinePair),
352         OrderOutlinePair);
353 }
354
355 #define HIST_SIZE 100
356 void HistogramMax(int *data,int dataLength,int offset,int sign,int *histogram)
357 {
358     int i,bin;
359
360     if (sign>0) {
361         int maxVal;
362
363         maxVal = *data;
364         for (i=0;i<dataLength; ++i)
365             if (data[i] != HIT_THE_BOX) {
366                 maxVal = data[i];
367                 break;
368             }
369         for (;i<dataLength; ++i)
370             if (data[i] != HIT_THE_BOX && data[i]>maxVal)
371                 maxVal = data[i];
372         if (maxVal != HIT_THE_BOX) {
373             bin = maxVal-offset;
374             if ((bin>=0)&&(bin<HIST_SIZE))
375                 histogram[bin]++;
376         }
377     }
378     else {
379         int minVal;
380         minVal = *data;

```

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```

381     for (i=0;i<dataLength; ++i)
382         if (data[i] != HIT_THE_BOX) {
383             minValue = data[i];
384             break;
385         }
386     for (;i<dataLength; ++i)
387         if (data[i] != HIT_THE_BOX && data[i] < minValue)
388             minValue = data[i];
389     if (minValue != HIT_THE_BOX) {
390         bin = minValue - offset;
391         if ((bin >= 0) && (bin < HIST_SIZE))
392             histogram[bin] ++;
393     }
394 }
395 }
396
397 void Histogram(int *data, int dataLength, int offset, int *histogram)
398 {
399     int i, bin;
400
401     for (i=0; i<dataLength; ++i) {
402         if (*data != HIT_THE_BOX) {
403             bin = *data - offset;
404             if ((bin >= 0) && (bin < HIST_SIZE))
405                 histogram[bin] ++;
406         }
407         data ++;
408     }
409 }
410
411 int MaxBin(int *histogram)
412 {
413     int i;
414     int maxValue;
415     int maxIndex;
416
417     maxValue = histogram[0];
418     maxIndex = 0;
419     for (i=0; i<HIST_SIZE; ++i)
420         if (histogram[i] > maxValue) {
421             maxValue = histogram[i];
422             maxIndex = i;
423         }
424     return maxIndex;
425 }
426
427 int MaxBinAbove(int *histogram, int line)
428 {
429     int i;
430     int maxValue;
431     int maxIndex;
432     int top, bottom;
433
434     for (i=0; i<HIST_SIZE; ++i)
435         if (histogram[i] != 0)

```

```

436         break;
437
438         top = i;
439         bottom = (line + top)/2;
440
441         maxValue = histogram[top];
442         maxIndex = top;
443         for (i=top; i<=bottom; ++i)
444             if (histogram[i]>maxValue) {
445                 maxValue = histogram[i];
446                 maxIndex = i;
447             }
448         return maxIndex;
449     }
450
451     void DrawTextLines(Picture thePict,Dictionary dict,int topLine,int bottomLine)
452     {
453         int maxLength;
454         int halfWidth;
455         int x,y;
456         float x2,x3,y2,y3;
457         float angle;
458
459         angle = (*(dict->rawOutlines))->box->angle;
460         maxLength = thePict->width + thePict->height;
461         halfWidth = thePict->width / 2;
462         x = topLine * -sin(angle) + halfWidth * cos(angle);
463         y = topLine * cos(angle) + halfWidth * sin(angle);
464         x2 = x + maxLength*cos(angle);
465         y2 = y + maxLength*sin(angle);
466         x3 = x - maxLength*cos(angle);
467         y3 = y - maxLength*sin(angle);
468         DrawLine(thePict,x,y,(int)x2,(int)y2,5);
469         DrawLine(thePict,x,y,(int)x3,(int)y3,5);
470
471         x = bottomLine * -sin(angle) + halfWidth * cos(angle);
472         y = bottomLine * cos(angle) + halfWidth * sin(angle);
473         x2 = x + maxLength*cos(angle);
474         y2 = y + maxLength*sin(angle);
475         x3 = x - maxLength*cos(angle);
476         y3 = y - maxLength*sin(angle);
477         DrawLine(thePict,x,y,(int)x2,(int)y2,5);
478         DrawLine(thePict,x,y,(int)x3,(int)y3,5);
479     }
480
481     void PageStatistics(Dictionary dict,char *fileName,NormalizationDescriptor *nd)
482     /* WARNING - this must be run before PostProcess since PostProcess changes the raw
483      * shape data. */
484     {
485         int index;
486         int temp;
487         int i,startIndex,firstY,minY,endIndex,shape;
488         int tops[HIST_SIZE];
489         int bottoms[HIST_SIZE];
490         int ascenders[HIST_SIZE];

```


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```

491     int descenders[HIST_SIZE];
492     int middleLine,topLine,bottomLine,ascenderLine,descenderLine;
493     int ascenderHeight,descenderHeight,lineNumber;
494     int fontXHeight,fontXWidth,xIndex;
495     RawOutlinePair thisShape;
496     FILE *fp;
497     BOOLEAN haveFirstFontXWidth = FALSE;
498     int firstFontXWidth;
499
500     if ((fp=fopen(fileName,"w"))==NULL)
501         DoError("PageStatistics: error opening output file %s.\n",fileName);
502
503     SortDictionary(dict);
504
505     index = 0;
506     #ifdef foo
507     malloc_verify();
508     #endif
509     lineNumber = 0;
510     while (index < dict->numberOfEntries) {
511         startIndex = index;
512         firstY = (*(dict->rawOutlines+index))->box->pageY;
513         minY = firstY;
514         while ( (*(dict->rawOutlines+index))->box->pageY - firstY < 20 &&
515                 (*(dict->rawOutlines+index))->box->pageY - firstY > -20) {
516             if (minY > (*(dict->rawOutlines+index))->box->pageY)
517                 minY = (*(dict->rawOutlines+index))->box->pageY;
518             ++index;
519             if (index == dict->numberOfEntries)
520                 break;
521         }
522         endIndex = index;
523
524     #ifdef foo
525     malloc_verify();
526     #endif
527
528     /* shapes from start index through endIndex are all on */
529     /* the same text line */
530     /* minY has the top of the highest box on the line. */
531
532     /* Find the base and topline by taking the mode of the heights of the
533     * valleys of the bottom contours and the peaks of the top contours */
534     for (i=0;i<HIST_SIZE;i++) {
535         tops[i]=0;
536         bottoms[i]=0;
537         ascenders[i]=0;
538         descenders[i]=0;
539     }
540
541     for (shape=startIndex;shape<endIndex; ++shape) {
542         thisShape = *(dict->rawOutlines+shape);
543         Histogram(thisShape->top,thisShape->numberOfLegs,minY,tops);
544         Histogram(thisShape->bottom,thisShape->numberOfLegs,minY,bottoms);
545

```

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```

546     HistogramMax(thisShape->top,thisShape->numberOfLegs,minY,-1,ascenders);
547     HistogramMax(thisShape->bottom,thisShape->numberOfLegs,minY,1,descenders);
548 }
549     topLine = MaxBin(tops)+minY;
550     bottomLine = MaxBin(bottoms)+minY;
551     ascenderLine = MaxBin(ascenders)+minY;
552     descenderLine = MaxBin(descenders)+minY;
553
554     if (thePict)
555         DrawTextLines(thePict,dict,topLine,bottomLine);
556 #ifdef foo
557     malloc_verify();
558 #endif
559
560     middleLine = (bottomLine+topLine)/2;
561     fontXHeight = bottomLine-topLine;
562     ascenderHeight = bottomLine-ascenderLine;
563     if ((float)ascenderHeight/(float)fontXHeight < 1.1) {
564         fprintf(stderr,"Bad ascender height on line %d.\n",lineNumber);
565         ascenderLine = MaxBinAbove(ascenders,ascenderLine-minY)+minY;
566         ascenderHeight = bottomLine-ascenderLine;
567         fprintf(stderr,"New ascender height = %d.\nNew xheight =
%d.\n",ascenderHeight,fontXHeight);
568     }
569
570     fprintf(fp,"%d: %d %d %2.6f\n",lineNumber,fontXHeight,ascenderHeight,
571         (float)ascenderHeight/(float)fontXHeight);
572
573 #ifdef foo
574     /* Assume that the first shape in the image is the letter x.
575      * Use this shape to compute the fontXWidth value. */
576     if (lineNumber==0)
577         fontXWidth = RawOutlineWidth(*(dict->rawOutlines),middleLine);
578 #endif
579
580     ++lineNumber;
581     if (fontXHeight < 0) {
582         fprintf(stderr,"PageStatistics: negative fontXHeight in line %d.\n",lineNumber);
583         fontXHeight *= -1;
584     }
585     for (shape=startIndex;shape<endIndex; ++shape)
586         StoreOutlinePair(dict,shape,middleLine,fontXHeight,ascenderHeight,nd);
587 } /* Do another line of text */
588 fclose(fp);
589 }

```

Jan 12 17:35 1991 getAll.c

```

1  #include <stdio.h>
2  #include <math.h>
3  #include <values.h>
4  #include "boolean.h"
5  #include "types.h"
6  #include "pict.h"
7  #include "dict.h"
8
9  #define MAX_STRING_LEN 256
10
11 void WriteShiftedAsciiOutline(FILE *fp, OutlinePair outline, float x, float y)
12 {
13     int i;
14     for (i=0; i<outline->numberOfLegs; ++i)
15         fprintf(fp, "%f %f\n", i+x, *(outline->top+i)+y);
16     fprintf(fp, "\ntop\n\n");
17
18     for (i=0; i<outline->numberOfLegs; ++i)
19         fprintf(fp, "%f %f\n", i+x, y-*(outline->bottom+i));
20     fprintf(fp, "\nbottom\n\n");
21 }
22
23 void WriteOutlines(char *filename, Dictionary dict)
24 {
25     float maxWidth, maxHeight;
26     int i, j, count;
27     int width, height;
28     float x, y;
29     OutlinePair outline;
30     FILE *fp;
31     if ((fp = fopen(filename, "w")) == NULL) {
32         printf("Error opening %s.", filename);
33         exit(-1);
34     }
35
36     maxWidth = 0;
37     maxHeight = 0;
38     for (i=0; i<dict->numberOfEntries; ++i) {
39         outline = *(dict->outlines+i);
40         if (outline->numberOfLegs > maxWidth)
41             maxWidth = outline->numberOfLegs;
42         for (j=0; j<outline->numberOfLegs; ++j) {
43             if (*(outline->bottom+j) > maxHeight)
44                 maxHeight = *(outline->bottom+j) > maxHeight;
45             if (*(outline->top+j) > maxHeight)
46                 maxHeight = *(outline->bottom+j) > maxHeight;
47         }
48     };
49
50     printf("maxWidth, maxHeight = %f, %f\n", maxWidth, maxHeight);
51
52     width = irint(sqrt((double)(dict->numberOfEntries)));

```

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```

53     height = irint((double)(dict->numberOfEntries) / width);
54
55     printf("n,width,height = %d,%d,%d\n",dict->numberOfEntries,width,height);
56
57     for (i=0;i<height; ++i)
58     for (j=0;j<width; ++j) {
59         count = i*width+j;
60         if ((count < 16) && (count < dict->numberOfEntries)) {
61             x = j*maxWidth*1.5;
62             y = (height-i+1)*maxHeight*3;
63             printf("(%f,%f) ",x,y);
64             WriteShiftedAsciiOutline(fp,*(dict->outlines+count),x,y);
65         }
66     }
67     fclose(fp);
68 }
69
70
71 void main(int argc,char **argv)
72 {
73     char *infile,*outfile;
74     Dictionary dict;
75
76     if (argc != 3) {
77         printf("Usage:\n");
78         printf(" %s infile outfile\n",argv[0]);
79         exit(-1);
80     }
81
82     infile = argv[1];
83     outfile = argv[2];
84     dict = ReadDictionary(infile);
85
86     WriteOutlines(outfile,dict);
87
88     printf("\n");
89 }
90
91

```

Jul 8 14:25 1991 getOutline.c

```

1    #include <stdio.h>
2    #include <math.h>
3    #include <values.h>
4    #include <strings.h>
5    #include "boolean.h"
6    #include "types.h"
7    #include "pict.h"
8    #include "dict.h"
9
10   extern char *strchr(char *s,int c);
11
12   #define MAX_STRING_LEN 256
13
14   void WriteAsciiOutline(char *filename, OutlinePair outline)
15   {
16       FILE *fp;
17       int i;
18       if ((fp = fopen(filename,"w")) == NULL) {
19           printf("Error opening %s.",filename);
20           exit(-1);
21       }
22       for (i=0;i<outline->numberOfLegs; ++i)
23           fprintf(fp,"%d %f\n",i,*(outline->top+i));
24       fprintf(fp,"\ntop\n\n");
25
26       for (i=0;i<outline->numberOfLegs; ++i)
27           fprintf(fp,"%d %f\n",i,-*(outline->bottom+i));
28       fprintf(fp,"\nbottom\n\n");
29       fclose(fp);
30   }
31
32
33   void main(int argc,char **argv)
34   {
35       char *infile;
36       char s[MAX_STRING_LEN],outfile[MAX_STRING_LEN];
37       Dictionary dict;
38       int selection;
39       char *crPointer;
40       BOOLEAN done = FALSE;
41
42       if (argc != 2) {
43           printf("Usage:\n");
44           printf(" %s infile\n",argv[0]);
45           exit(-1);
46       }
47
48       infile = argv[1];
49       dict = ReadDictionary(infile);
50
51       while (!done) {
52           printf("Shape number [0..%d]: ",dict->numberOfEntries-1);

```

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```

53 fgets(s,MAX_STRING_LEN,stdin);
54 if (sscanf(s,"%d",&selection) == 1) {
55     if (selection < 0 || selection >= dict->numberOfEntries)
56         printf("Shape numbers must be between 0 and %d, inclusive.\n",
57             dict->numberOfEntries-1);
58     else {
59         printf("Output file: ");
60         fgets(outfile,MAX_STRING_LEN,stdin);
61         crPointer = strchr(outfile,'\n');
62         if (crPointer != NULL)
63             *crPointer = '\0';
64         printf("Writing shape %d to file %s\n",selection,outfile);
65         WriteAsciiOutline(outfile,*(dict->outlines + selection));
66     }
67 }
68 else if ((s[0] == '\0') || (s[0] == '\n'))
69     done = TRUE;
70 else {
71     printf("Enter an integer to select a shape or a blank line\n");
72     printf("to quit.\n");
73 }
74 }
75 }
76
77

```

Jan 11 17:06 1991 gaussian.c

```

1  #include <stdio.h>
2  #include <math.h>
3  #include <values.h>
4
5  float square(float x)
6  {
7      return x*x;
8  }
9
10 float gaussian(a, s, x) /* return A*GAUSS(SIGMA, X) */
11 float a, s, x;
12 {
13     return (a*exp(-square(x/s)/2.0))/(s*sqrt(2.0*M_PI));
14 }
15
16 float *MakeMask(int halfMaskSize, float a)
17 {
18     int mask_size;
19     int x;
20     float s;
21     float *mask, sum;
22
23     mask_size = 2*halfMaskSize + 1;
24     s = halfMaskSize/2;
25     mask = (float *) calloc(halfMaskSize + 1, sizeof(float));
26     if (mask == NULL) {
27         printf("MakeMask: cannot allocate space\n");
28         exit(-1);
29     }
30
31     for (x = 0; x <= halfMaskSize; x++) {
32         mask[x] = gaussian(a, s, (float) x);
33     /* printf("%e\n", mask[x]); */
34     }
35
36     for (sum = fabs(mask[0]), x = 1; x <= halfMaskSize; x++)
37         sum += 2.0*fabs(mask[x]);
38
39     for (x = 0; x <= halfMaskSize; x++)
40         mask[x] /= sum;
41
42     return mask;
43 }
44
45 void Guass1DFloat(float *data, int n, int halfMaskSize)
46 {
47     float a;
48     float *mask;
49     float *newData;
50     float *leftPtr, *rightPtr;
51     float sum;
52     int i, j, left, right;

```

```

53
54     a = 1;
55
56     if (n < halfMaskSize*2 + 1)
57         return;
58
59     newData = (float *)calloc(n, sizeof(float));
60     if (newData == NULL) {
61         printf("Guass1DFloat: cannot allocate space\n");
62         exit(-1);
63     }
64
65     mask = MakeMask(halfMaskSize, a);
66
67     for (i = halfMaskSize; i < n - halfMaskSize; ++i) {
68         sum = *(data + i) * mask[0];
69         leftPtr = rightPtr = data + i;
70         for (j = 1; j < halfMaskSize; ++j)
71             sum += mask[j] * (*(-leftPtr) + *(++rightPtr));
72         newData[i] = sum;
73     }
74
75     for (i = 0; i < halfMaskSize; ++i) {
76         sum = data[i] * mask[0];
77         left = i;
78         right = i;
79         for (j = 1; j < halfMaskSize; ++j) {
80             if (--left < 0)
81                 left += n;
82             if (++right >= n)
83                 right -= n;
84             sum += mask[j] * (data[left] + data[right]);
85         }
86         newData[i] = sum;
87     }
88
89     for (i = n - halfMaskSize; i < n; ++i) {
90         sum = data[i] * mask[0];
91         left = i;
92         right = i;
93         for (j = 1; j < halfMaskSize; ++j) {
94             if (--left < 0)
95                 left += n;
96             if (++right >= n)
97                 right -= n;
98             sum += mask[j] * (data[left] + data[right]);
99         }
100         newData[i] = sum;
101     }
102
103     leftPtr = data;
104     rightPtr = newData;
105     for (i = 0; i < n; ++i)
106         *leftPtr++ = *rightPtr++;
107     free(newData);

```


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5,491,760

438

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108 }

Aug 23 19:21 1991 lines.c

```

1  #include <stdio.h>
2  #include <values.h>
3  #include <math.h>
4  #include "boolean.h"
5  #include "pict.h"
6  #include "lines.h"
7
8  void LineEngine(Picture pict,
9                  int x1,
10                 int y1,
11                 int x2,
12                 int y2,
13                 UCHAR color,
14                 pistFunc PerPixel)
15  {
16      static int inside = 0;
17      int xinc,yinc;
18      int distance;
19      int left,right,top,bottom;
20
21      ++inside;
22      left = 0;
23      right = pict->width-1;
24      top = 0;
25      bottom = pict->height-1;
26      /* printf("Draw line: (%d,%d)-(%d,%d)\n",x1,y1,x2,y2); */
27      /* CASE VERTICAL */
28      yinc = y2 - y1;
29      xinc = x2 - x1;
30      if (xinc > 0) {
31          if (yinc > 0) {
32              /* Line goes up to the right */
33              if (yinc > xinc)
34                  distance = -yinc;
35              else
36                  distance = xinc;
37              while ((*PerPixel)(pict,x1,y1,
38                              ((x1 < x2) || (y1 < y2)) && (x1 <= right) && (y1 <= bottom),
39                              color)) {
40                  if (distance > 0) {
41                      /* move right */
42                      x1++;
43                      distance -= yinc;
44                  } else {
45                      /* move up */
46                      y1++;
47                      distance += xinc;
48                  }
49              }
50          } else {
51              if (-yinc > xinc)
52                  distance = yinc;

```

```

53     else
54         distance = xinc;
55     while ((*PerPixel)(pict,x1,y1,
56                 ((x1 < x2) || (y1 > y2))&&(x1 <= right)&&(y1 >= top),
57                 color)) {
58         if (distance > 0) {
59             /* move right */
60             x1++;
61             distance += yinc;
62         } else {
63             /* move down */
64             y1--;
65             distance += xinc;
66         }
67     }
68 }
69 } else {
70     if (yinc > 0) {
71         /* Line goes up to the left */
72         if (yinc > -xinc)
73             distance = -yinc;
74     } else
75         distance = -xinc;
76     while ((*PerPixel)(pict,x1,y1,
77                 ((x1 > x2) || (y1 < y2))&&(x1 >= left)&&(y1 <= bottom),
78                 color)) {
79         if (distance > 0) {
80             /* move left */
81             x1--;
82             distance -= yinc;
83         } else {
84             /* move up */
85             y1++;
86             distance -= xinc;
87         }
88     }
89 } else {
90     if (-yinc > -xinc)
91         distance = yinc;
92     else
93         distance = -xinc;
94     while ((*PerPixel)(pict,x1,y1,
95                 ((x1 > x2) || (y1 > y2))&&(x1 >= left)&&(y1 >= top),
96                 color)) {
97         if (distance > 0) {
98             /* move left */
99             x1--;
100             distance += yinc;
101         } else {
102             /* move down */
103             y1--;
104             distance -= xinc;
105         }
106     }
107 }

```

```

108     }
109     --inside;
110 }
111
112 BOOLEAN DrawPiston(Picture pict, int x, int y, BOOLEAN test, UCHAR color)
113 {
114     if (test)
115         WriteClippedPixel(pict,x,y,color);
116     return test;
117 }
118
119 static UCHAR bitmasks[] = { 0x80,0x40,0x20,0x10,0x8,0x4,0x2,0x1 };
120
121 void CountLine1Bit(Picture pict,
122                   int x1,
123                   int y1,
124                   int x2,
125                   int y2,
126                   int *totalSet,
127                   int *total)
128 {
129     static int inside = 0;
130     int xinc,yinc;
131     int distance;
132     int left,right,top,bottom;
133
134     int uchar_width;
135     UCHAR *cursor;
136     UCHAR mask;
137     int count = 0;
138     int pixels = 0;
139
140     ++inside;
141     left = 0;
142     right = pict->width-1;
143     top = 0;
144     bottom = pict->height-1;
145
146     if (pict->depth != 1)
147         DoError("CountLine1Bit: Only depth 1 is supported.\n",NULL);
148
149     uchar_width = pict->uchar_width;
150     cursor = pict->data+y1*uchar_width+(x1>>3);
151     mask = bitmasks[x1%8];
152
153     /* printf("Draw line: (%d,%d)-(%d,%d)\n",x1,y1,x2,y2); */
154     /* CASE VERTICAL */
155     yinc = y2 - y1;
156     xinc = x2 - x1;
157     if (xinc > 0) {
158         if (yinc > 0) {
159             /* Line goes up to the right */
160             if (yinc > xinc)
161                 distance = -yinc;
162             else

```

```

163     distance = xinc;
164     while (((x1 < x2) || (y1 < y2)) && (x1 <= right) && (y1 <= bottom)) {
165         if (*cursor & mask)
166             ++count;
167         ++pixels;
168         if (distance > 0) {
169             /* move right */
170             if (mask == 0x1) {
171                 mask = 0x80;
172                 ++cursor;
173             }
174             else
175                 mask = mask >> 1;
176             x1++;
177             distance -= yinc;
178         } else {
179             /* move up */
180             cursor += uchar_width;
181             y1++;
182             distance += xinc;
183         }
184     }
185 } else {
186     if (-yinc > xinc)
187         distance = yinc;
188     else
189         distance = xinc;
190     while (((x1 < x2) || (y1 > y2)) && (x1 <= right) && (y1 >= top)) {
191         if (*cursor & mask)
192             ++count;
193         ++pixels;
194         if (distance > 0) {
195             /* move right */
196             if (mask == 0x1) {
197                 mask = 0x80;
198                 ++cursor;
199             }
200             else
201                 mask = mask >> 1;
202             x1++;
203             distance += yinc;
204         } else {
205             /* move down */
206             cursor -= uchar_width;
207             y1--;
208             distance += xinc;
209         }
210     }
211 }
212 } else {
213     if (yinc > 0) {
214         /* Line goes up to the left */
215         if (yinc > -xinc)
216             distance = -yinc;
217         else

```

```

218     distance = -xinc;
219     while (((x1 > x2) || (y1 < y2)) && (x1 >= left) && (y1 <= bottom)) {
220         if (*cursor & mask)
221             ++count;
222         ++pixels;
223         if (distance > 0) {
224             /* move left */
225             if (mask == 0x80) {
226                 mask = 0x1;
227                 --cursor;
228             }
229             else
230                 mask = mask << 1;
231             x1--;
232             distance -= yinc;
233         } else {
234             /* move up */
235             cursor += uchar_width;
236             y1++;
237             distance -= xinc;
238         }
239     }
240 } else {
241     if (-yinc > -xinc)
242         distance = yinc;
243     else
244         distance = -xinc;
245     while (((x1 > x2) || (y1 > y2)) && (x1 >= left) && (y1 >= top)) {
246         if (*cursor & mask)
247             ++count;
248         ++pixels;
249         if (distance > 0) {
250             /* move left */
251             if (mask == 0x80) {
252                 mask = 0x1;
253                 --cursor;
254             }
255             else
256                 mask = mask << 1;
257             x1--;
258             distance += yinc;
259         } else {
260             /* move down */
261             cursor -= uchar_width;
262             y1--;
263             distance -= xinc;
264         }
265     }
266 }
267 }
268 --inside;
269 *totalSet += count;
270 *total += pixels;
271 }
272

```

```

273 void DrawLine(Picture pict, int x1, int y1, int x2, int y2, UCHAR color)
274 {
275     LineEngine(pict,x1,y1,x2,y2,color,DrawPiston);
276 }
277
278 static int pixelCounter;
279 static int setCounter;
280 BOOLEAN CountPiston(Picture pict, int x, int y, BOOLEAN test, UCHAR color)
281 {
282     if (test) {
283         ++ pixelCounter;
284         if (ReadPixel(pict,x,y))
285             ++ setCounter;
286     }
287     return test;
288 }
289
290 #ifdef foo
291 float CountLine(Picture pict, int x1, int y1, int x2, int y2)
292 {
293     pixelCounter = 0;
294     setCounter = 0;
295     LineEngine(pict,x1,y1,x2,y2,0,CountPiston);
296     LineEngine(pict,x1,y1,x1-(x2-x1),y1-(y2-y1),0,CountPiston);
297     return (float)setCounter/pixelCounter;
298 }
299 #endif
300
301 float CountLine(Picture pict, int x1, int y1, int x2, int y2)
302 {
303     pixelCounter = 0;
304     setCounter = 0;
305     CountLine1Bit(pict,x1,y1,x2,y2,&setCounter,&pixelCounter);
306     CountLine1Bit(pict,x1,y1,x1-(x2-x1),y1-(y2-y1),&setCounter,&pixelCounter);
307     return (float)setCounter/pixelCounter;
308 }
309
310 static int startx;
311 static int starty;
312 static int endx;
313 static int endy;
314 BOOLEAN DistancePiston(Picture pict, int x, int y, BOOLEAN test, UCHAR color)
315 {
316     if (test) {
317         if (ReadPixel(pict,x,y)) {
318             if ((x == startx)&&(y == starty))
319                 return test;
320             else {
321                 endx = x;
322                 endy = y;
323                 return FALSE;
324             }
325         }
326     }
327     return test;

```

```

328     } else
329     return test;
330 }
331
332
333 int DistanceLine(Picture pict, int x1, int y1, int x2, int y2)
334 {
335     double dx,dy;
336     startx = x1;
337     starty = y1;
338     endx = x2;
339     endy = y2;
340     LineEngine(pict,x1,y1,x2,y2,0,DistancePiston);
341     dx = endx-x1;
342     dy = endy-y1;
343     return sqrt(dx*dx+dy*dy);
344 }
345
346
347 #ifdef TEST
348 void draw(pict)
349 Picture pict;
350 {
351     float angle;
352     float step;
353     float x1,y1,x2,y2;
354     float r1,r2;
355     int xc,yc;
356
357     xc = 320;
358     yc = 250;
359     r1 = 50;
360     r2 = 400;
361     step = M_PI*2/50;
362
363     for (angle = 0; angle < 2*M_PI; angle += step) {
364         x1 = xc + r1*cos(angle);
365         y1 = yc + r1*sin(angle);
366         x2 = xc + r2*cos(angle);
367         y2 = yc + r2*sin(angle);
368         DrawLine(pict,(int)x1,(int)y1,(int)x2,(int)y2,0xff);
369         printf("%3.2f: %d %d\n",angle,
370             CountLine(pict,(int)x1,(int)y1,(int)x2,(int)y2),
371             DistanceLine(pict,(int)x1,(int)y1,(int)x2,(int)y2));
372     }
373 }
374
375 void main(argc,argv)
376 int argc;
377 char **argv;
378 {
379     char *outfile;
380     Picture pict;
381
382     if (argc != 2) {

```


Section D

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```
383     printf("Usage: %s outfile\n",argv[0]);
384     exit(0);
385 }
386 outfile = argv[1];
387
388 pict = new_pict(640,500,1);
389
390 draw(pict);
391
392 write_pict(outfile,pict);
393 printf("done\n");
394 }
395 #endif
```

Aug 23 16:43 1991 maxFilter.c

```

1  #include <stdio.h>
2  #include "mylib.h"
3
4  extern int irint(double);
5
6  #define MAX_SIGNAL_LENGTH (10000)
7  #define MIN_MODE (5) /* MIN_MODE must be less than MAX_HIST_SIZE */
8  #define MAX_HIST_SIZE (500)
9  #define MAX_PEAKS (100)
10 #define BASE_PERCENTILE (0.5)
11 float data[MAX_SIGNAL_LENGTH];
12 int newSignal[MAX_SIGNAL_LENGTH];
13
14 int MaxOnInterval(int start,int end)
15 {
16     int i;
17     float maxValue = data[start];
18     int maxIndex = start;
19     for (i=start;i<end; + i)
20         if (data[i]>maxValue) {
21             maxValue = data[i];
22             maxIndex = i;
23         }
24     return maxIndex;
25 }
26
27 void main(int argc,char **argv)
28 {
29     char *infile,*outfile;
30     FILE *inFP,*outFP;
31     int signalLength;
32     float *cursor;
33     int foo;
34     int i;
35     int maskWidth = 10;
36     float maxValue;
37     int maxIndex,modeValue,modelIndex;
38     int h[MAX_HIST_SIZE];
39     int finalCount;
40     int finalIndex[MAX_PEAKS];
41     float baseThresh;
42     BOOLEAN upState;
43     float thisRatio,lastRatio;
44
45     DefArg("%s %s","infile outfile",&infile,&outfile);
46     ScanArgs(argc,argv);
47
48     if ((inFP=fopen(infile,"r"))==NULL)
49         DoError("Error opening file %s.\n",infile);
50
51     cursor = data;
52     while (fscanf(inFP,"%d %f\n",&foo,cursor++ )==2)

```

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```

53     if (cursor-data > MAX_SIGNAL_LENGTH)
54         DoError("Signal is too long.\n", NULL);
55     signalLength = cursor-data;
56
57     /* Compute the threshold for the black edge to black pixel ratio */
58     maxValue = data[0];
59     for (i=0; i<signalLength; ++i) {
60         if (data[i] > maxValue)
61             maxValue = data[i];
62     }
63     baseThresh = maxValue*BASE_PERCENTILE;
64     printf("baseThresh = %3.3f\n", baseThresh);
65
66     /* Get the indices of the peaks taller than baseThresh */
67     finalCount = 0;
68     upState = TRUE;
69     for (i=0; i<signalLength; ++i) {
70         thisRatio = data[i];
71         if (thisRatio < baseThresh)
72             thisRatio = 0;
73         if (upState) {
74             if (thisRatio < lastRatio) {
75                 finalIndex[finalCount] = i;
76                 finalCount++;
77                 upState = FALSE;
78             }
79         }
80         else {
81             /* upState == FALSE */
82             if (thisRatio > lastRatio)
83                 upState = TRUE;
84         }
85         lastRatio = thisRatio;
86         if (finalCount == MAX_PEAKS)
87             break;
88     }
89
90     /* Histogram the distances between adjacent peaks */
91     for (i=0; i<MAX_HIST_SIZE; h[i]=0);
92     for (i=0; i<finalCount-1; ++i) {
93         int d;
94         d = finalIndex[i+1]-finalIndex[i];
95         if (d < MAX_HIST_SIZE)
96             h[d]++;
97     }
98
99     /* Find the mode of the adjacent distances that is above MIN_MODE */
100     modeValue = h[MIN_MODE];
101     modeIndex = MIN_MODE;
102     for (i=MIN_MODE; i<MAX_HIST_SIZE; ++i)
103         if (h[i] > modeValue) {
104             modeValue = h[i];
105             modeIndex = i;
106         }
107

```

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```
108  /* Set the mask width to half of the most common spacing of largest peaks */
109  maskWidth = rint(modelIndex*0.80);
110  printf("maskWidth = %d.\n",maskWidth);
111
112  for (i=0;i<signalLength;newSignal[i++] = 0);
113  for (i=0;i<signalLength-maskWidth; ++i)
114    newSignal[MaxOnInterval(i,i+maskWidth)] ++;
115
116  if ((outFP=fopen(outfile,"w")) == NULL)
117    DoError("Error opening file %s.\n",NULL);
118  for (i=0;i<signalLength; ++i)
119    fprintf(outFP,"%d %d\n",i,newSignal[i]);
120  fclose(outFP);
121  }
122
123
124
```

Jun 19 21:22 1991 myWc.c

```

1  #include <stdio.h>
2  #include "boolean.h"
3  #include "error.h"
4
5  typedef int State;
6  #define WHITE_SPACE 0
7  #define UNKNOWN_WORD 1
8  #define ASCENDER_WORD 2
9
10
11 #define MAX_STRING_LENGTH 200
12
13 BOOLEAN isWhite(char c)
14 {
15     return (c == ' ' || c == '\t' || c == '\0' || c == '\n');
16 }
17
18 BOOLEAN isAscender(char c)
19 {
20     return ((c == 'b') || (c == 'd') || (c == 'f') || (c == 'h') || (c == 'i') || (c == 'j') || (c == 'k') || (c == 'l') ||
21             (c == 't') || ((c >= 'A') && (c <= 'Z')) || ((c >= '0') && (c <= '9')) || (c == '\v') || (c == '\0'));
22 }
23
24 void main(int argc, char **argv)
25 {
26     char *filename;
27     FILE *fp;
28     char s[MAX_STRING_LENGTH + 1];
29     char *ptr;
30     State state;
31     int wordsWithAscenders, wordsWithoutAscenders, words;
32
33     if (argc != 2) {
34         fprintf(stderr, "Usage: \n");
35         fprintf(stderr, " %s <input file> \n");
36         exit(-1);
37     }
38
39     filename = argv[1];
40     if ((fp = fopen(filename, "r")) == NULL)
41         DoError("%s: cannot open input file.\n", filename);
42
43     wordsWithAscenders = 0;
44     wordsWithoutAscenders = 0;
45     words = 0;
46     fgets(s, MAX_STRING_LENGTH, fp);
47     while (!feof(fp)) {
48         ptr = s;
49         state = WHITE_SPACE;
50         while (*ptr != '\0') {
51             switch (state) {
52                 case WHITE_SPACE:

```

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```

53         if (isWhite(*ptr))
54             ++ptr;
55         else
56             state = UNKNOWN_WORD;
57         break;
58     case UNKNOWN_WORD:
59         if (isWhite(*ptr)) {
60             ++wordsWithoutAscenders;
61             ++words;
62             state = WHITE_SPACE;
63         }
64         if (isAscender(*ptr)) {
65             ++wordsWithAscenders;
66             ++words;
67             ++ptr;
68             state = ASCENDER_WORD;
69         }
70         else
71             ++ptr;
72         break;
73     case ASCENDER_WORD:
74         if (isWhite(*ptr))
75             state = WHITE_SPACE;
76         ++ptr;
77         break;
78     default:
79         DoError("myWc: internal error - bad state.\n",NULL);
80     } /* switch */
81 } /* while (*ptr ... */
82 fgets(s,MAX_STRING_LENGTH,fp);
83 } /* while (feof ... */
84 printf("words: %d\n",words);
85 printf("words with ascenders: %d\n",wordsWithAscenders);
86 printf("words without ascenders: %d\n",wordsWithoutAscenders);
87 printf("word ascender/descender ratio: %6.2f\n",
88        (float)wordsWithAscenders/(float)wordsWithoutAscenders);
89 }

```

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Aug 23 18:12 1991 newBaselines.c

```

1  #include <stdio.h>
2  #include <values.h>
3  #include <math.h>
4  #include "boolean.h"
5  #include "pict.h"
6  #include "types.h"
7  #include "lists.h"
8  #include "lines.h"
9  #include "baselines.h"
10
11 extern double sqrt(double);
12 extern int irint(double);
13
14 /*inline*/ int NewReadPixel(UCHAR *base,int width,float x,float y)
15 {
16     int xi;
17     int yi;
18     UCHAR mask;
19
20     xi = irint(x);
21     yi = irint(y);
22     mask = 0x80 >> (xi & 0x7);
23     return *(base+yi*width+(xi>>3)) & mask;
24 }
25
26 void NewCountLine1Bit(Picture pict,int x1,int y1,int x2,int y2,int *black,int *blackEdge)
27 {
28     float x,y;
29     float xinc,yinc;
30     float xupinc,yupinc;
31     float den;
32     int b,be;
33     int width,ucharWidth,height;
34     UCHAR *data;
35
36     width = pict->width;
37     ucharWidth = pict->uchar_width;
38     height = pict->height;
39     data = pict->data;
40
41     den = sqrt((y2-y1)*(y2-y1)+(x2-x1)*(x2-x1));
42     xinc = (x2-x1)/den;
43     yinc = (y2-y1)/den;
44     xupinc = -yinc;
45     yupinc = xinc;
46     x = x1;
47     y = y1;
48
49     b=0;
50     be=0;
51
52     while (x<width&&x>=0&&y<height&&y>=0) {

```

```

53     ++ b;
54     if (NewReadPixel(data,ucharWidth,x,y)) {
55         if (!(NewReadPixel(data,ucharWidth,x+xupinc,y+yupinc) &&
56             NewReadPixel(data,ucharWidth,x-xupinc,y-yupinc)))
57             ++ be;
58     }
59     x += xinc;
60     y += yinc;
61
62 }
63 *black = b;
64 *blackEdge = be;
65 }
66
67
68 #define MIN_BLACK 5
69 void NewCountLine(Picture pict,int x1,int y1,int x2,int y2,int *black,int *blackEdge)
70 {
71     *black = 0;
72     *blackEdge = 0;
73     NewCountLine1Bit(pict,x1,y1,x2,y2,black,blackEdge);
74     NewCountLine1Bit(pict,x1,y1,x1-(x2-x1),y1-(y2-y1),black,blackEdge);
75 }
76
77 static float x2offset;
78 static float y2offset;
79 static int projectIndex;
80 static int *blackPixels;
81 static int *blackEdgePixels;
82 static int *coorcx;
83 static int *coorcy;
84 BOOLEAN BaseLinePiston(Picture pict, int x, int y, BOOLEAN test, UCHAR color)
85 {
86     if (test) {
87         NewCountLine(pict,x,y,(int)(x+x2offset),(int)(y+y2offset),
88             blackPixels+projectIndex,blackEdgePixels+projectIndex);
89         coorcx[projectIndex] = x;
90         coorcy[projectIndex++] = y;
91         return test;
92     } else
93         return test;
94 }
95
96 static int lastX;
97 static int lastY;
98 BOOLEAN EndPointPiston(Picture pict, int x, int y, BOOLEAN test, UCHAR color)
99 {
100     if (test) {
101         lastX = x;
102         lastY = y;
103     }
104     return test;
105 }
106
107 void EndPoints(Picture pict,double angle,int *tx, int *ty,int *bx, int *by)

```


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```

108 {
109     int xc,yc;
110     int maxLength;
111     float normal;
112     float x2,y2,x3,y3;
113
114     /* Make normal to text point in quadrants I and II */
115     /* Assume 0 <= angle < 2*M_PI */
116     normal = fmod(angle + M_PI/2,2*M_PI);
117     if (normal > M_PI)
118         normal -= M_PI;
119
120     xc = pict->width/2;
121     yc = pict->height/2;
122
123     maxLength = pict->width+pict->height;
124     x2 = xc+maxLength*cos(normal); /* At bottom of picture */
125     y2 = yc+maxLength*sin(normal);
126     x3 = xc-maxLength*cos(normal); /* At top of picture */
127     y3 = yc-maxLength*sin(normal);
128
129     LineEngine(pict,xc,yc,(int)x2,(int)y2,0,EndPointPiston);
130     *bx = lastX;
131     *by = lastY;
132     LineEngine(pict,xc,yc,(int)x3,(int)y3,0,EndPointPiston);
133     *tx = lastX;
134     *ty = lastY;
135 }
136
137 double distance(int x1,int y1,int x2,int y2)
138 {
139     return sqrt((double)((x1-x2)*(x1-x2)+(y1-y2)*(y1-y2)));
140 }
141
142 FILE *PlotBaselineContour(char *plotFile,int topCount,
143                           float *ratios,int *newSignal,
144                           float baseThresh)
145 {
146     FILE *outfile;
147     int i;
148
149     printf("Opening baselines plot file\n");
150     if ((outfile = fopen(plotFile,"w")) == NULL) {
151         printf("Error opening baseline plot file.\n");
152         exit(-1);
153     }
154     for (i=0;i<topCount; ++i)
155         fprintf(outfile,"%d %f\n",i,ratios[i]/baseThresh*5);
156     fprintf(outfile,"\n\"Ratio\n\n");
157     for (i=0;i<topCount; ++i)
158         fprintf(outfile,"%d %d\n",i,newSignal[i]);
159     fprintf(outfile,"\n\"Projection\n\n");
160     fprintf(outfile,
161             "0 %f\n%d %f\n\n\"Baseline Threshold\n",
162             baseThresh,topCount,baseThresh);

```

```

163     return outfile;
164 }
165
166 int MaxOnInterval(float *data,int start,int end)
167 {
168     int i;
169     float maxValue = data[start];
170     int maxIndex = start;
171     for (i=start;i<end; ++i)
172         if (data[i]>maxValue) {
173             maxValue = data[i];
174             maxIndex = i;
175         }
176     return maxIndex;
177 }
178
179 #define BASE_PERCENTILE 0.50
180 #define MIN_LINE_HEIGHT_FRACTION 0.50
181 #define MIN_MODE (5) /* MIN_MODE must be less than MAX_HIST_SIZE */
182 #define MAX_HIST_SIZE (500)
183 #define MAX_BASELINES (300)
184 List Baselines(Picture pict,double angle,char *plotFile)
185 {
186     float *topProjection;
187     int *topCoordx,*topCoordy;
188     int *finalCoordx,*finalCoordy,*finalIndex;
189     int topIndex,bottomIndex;
190     int topCount,botCount,finalCount;
191     int maxLength;
192     int xc,yc;
193     float x2,y2,x3,y3;
194     float maxValue,lastValue;
195     int i,j;
196     float baseThresh;
197     int topX,topY,bottomX,bottomY;
198     BOOLEAN onTextLine;
199     List xList,yList,result;
200     double totalDistance,averageDistance;
201     FILE *outfile;
202     int inside;
203     BOOLEAN upState;
204     float ratio,lastRatio,thisRatio;
205     float *ratios;
206     int *newSignal;
207     int halfMaskWidth = 10; /* for computing ratios */
208     int maxIndex,modeValue,modelIndex;
209     int h[MAX_HIST_SIZE];
210     int maskWidth; /* for max filter */
211
212     printf("angle = %3.3f\n",angle);
213
214     /* The longest ling though the picture will be shorter than maxLength */
215     maxLength = pict->width + pict->height;
216
217     /* Allocate space for the page projection values */

```

```

218     blackPixels = (int *)calloc(maxLength,sizeof(int));
219     blackEdgePixels = (int *)calloc(maxLength,sizeof(int));
220     ratios = (float *)calloc(maxLength,sizeof(float));
221     newSignal = (int *)calloc(maxLength,sizeof(int));
222     topCoordx = (int *)calloc(maxLength,sizeof(int));
223     topCoordy = (int *)calloc(maxLength,sizeof(int));
224     finalCoordx = (int *)calloc(maxLength,sizeof(int));
225     finalCoordy = (int *)calloc(maxLength,sizeof(int));
226     finalIndex = (int *)calloc(maxLength,sizeof(int));
227
228     if ((blackPixels == NULL)||
229         (blackEdgePixels == NULL)||
230         (ratios == NULL)||
231         (newSignal == NULL)||
232         (topCoordx == NULL)||
233         (topCoordy == NULL)||
234         (finalIndex == NULL) ||
235         (finalCoordx == NULL) ||
236         (finalCoordy == NULL)) {
237         printf("BaseLines: cannot allocate memory\n");
238         exit(-1);
239     }
240
241     /* Compute the endpoints of a line through the center of the picture in the direction
242     * perpendicular to the text lines. This line will be used as the reference frame for
243     * computing projections. */
244     EndPoints(pict,angle,&topX,&topY,&bottomX,&bottomY);
245
246     printf("Main Line: (%d,%d)-(%d,%d)\n",topX,topY,bottomX,bottomY);
247     /* DrawLine(pict,topX,topY,bottomX,bottomY,0xff); */
248
249     /* Compute the projection of the image at each point along the line.
250     * topProjection will have the number of black pixels on a line and
251     * ratios will have the fraction of black pixels on a line that are
252     * the ends of vertical extents. */
253     x2offset = maxLength*cos(angle);
254     y2offset = maxLength*sin(angle);
255     projectIndex = 0;
256     coordx = topCoordx;
257     coordy = topCoordy;
258     LineEngine(pict,topX,topY,bottomX,bottomY,0,BaseLinePiston);
259     topCount = projectIndex;
260
261     /* Compute the ratios plot */
262     for (i=0;i<halfMaskWidth; ++i)
263         ratios[i] = 0;
264     for (i=topCount-halfMaskWidth;i<topCount; ++i)
265         ratios[i] = 0;
266     for (i=0,inside=0;i<halfMaskWidth*2+1; ++i)
267         inside += blackPixels[i];
268     for (i=halfMaskWidth;i<topCount-halfMaskWidth; ++i) {
269         ratios[i] = (float)blackEdgePixels[i]/inside;
270         inside -= blackPixels[i-halfMaskWidth];
271         inside += blackPixels[i+halfMaskWidth];
272     }

```

```

273
274 /* Compute the threshold for the black edge to black pixel ratio */
275 maxValue = ratios[0];
276 for (i=0;i<topCount; + i) {
277     if (ratios[i]>maxValue)
278         maxValue = ratios[i];
279 }
280
281 baseThresh = maxValue*BASE_PERCENTILE;
282 printf("baseThresh = %3.3f\n",baseThresh);
283
284 /* Get the coordinates of the baselines and topline by finding peaks in the
285 * ratios projection. */
286 finalCount = 0;
287 upState = TRUE;
288 for (i=0;i<topCount; + i) {
289     thisRatio = ratios[i];
290     if (thisRatio < baseThresh)
291         thisRatio = 0;
292     if (upState) {
293         if (thisRatio < lastRatio) {
294             finalIndex[finalCount] = i;
295             finalCount++;
296             upState = FALSE;
297         }
298     }
299     else {
300         /* upState == FALSE */
301         if (thisRatio > lastRatio)
302             upState = TRUE;
303     }
304     lastRatio = thisRatio;
305     if (finalCount == MAX_BASELINES) {
306         fprintf(stderr,"Warning: found too many baselines.\n");
307         fprintf(stderr,"Ignoring remaining baselines.\n");
308         break;
309     }
310 }
311
312 /* Histogram the distances between adjacent peaks */
313 for (i=0;i<MAX_HIST_SIZE;h[i] += 0);
314 for (i=0;i<finalCount-1; + i) {
315     int d;
316     d = finalIndex[i+1]-finalIndex[i];
317     if (d<MAX_HIST_SIZE)
318         h[d]++;
319 }
320
321 /* Find the mode of the adjacent distances that is above MIN_MODE */
322 modeValue = h[MIN_MODE];
323 modeIndex = MIN_MODE;
324 for (i=MIN_MODE;i<MAX_HIST_SIZE; + i)
325     if (h[i]>modeValue) {
326         modeValue = h[i];
327         modeIndex = i;

```

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```

328     }
329
330     /* Set the mask width to half of the most common spacing of largest peaks */
331     maskWidth = irint(modelIndex*0.80);
332     printf("maskWidth = %d.\n",maskWidth);
333
334     for (i=0;i<topCount;newSignal[i++] = 0);
335     for (i=0;i<topCount-maskWidth; ++i)
336         newSignal[MaxOnInterval(ratios,i+maskWidth)] ++;
337
338     /* Plot the baseline contour if requested */
339     if (plotFile!=NULL)
340         outfile = PlotBaselineContour(plotFile,topCount,ratios,newSignal,baseThresh);
341
342     /* Pick off the new peaks */
343     /* Compute the threshold for the black edge to black pixel ratio */
344     maxValue = newSignal[0];
345     for (i=0;i<topCount; ++i) {
346         if (newSignal[i]>maxValue)
347             maxValue = newSignal[i];
348     }
349
350     baseThresh = maxValue*0.80;
351     printf("baseThresh = %3.3f\n",baseThresh);
352
353     /* Get the coordinates of the baselines and toplines by finding peaks in the
354     * ratios projection. */
355     finalCount = 0;
356     upState = TRUE;
357     for (i=0;i<topCount; ++i) {
358         thisRatio = newSignal[i];
359         if (thisRatio < baseThresh)
360             thisRatio = 0;
361         if (upState) {
362             if (thisRatio < lastRatio) {
363                 finalCoordx[finalCount] = topCoordx[i];
364                 finalCoordy[finalCount] = topCoordy[i];
365                 finalIndex[finalCount] = i;
366                 finalCount++;
367                 upState = FALSE;
368             }
369         }
370         else {
371             /* upState == FALSE */
372             if (thisRatio > lastRatio)
373                 upState = TRUE;
374         }
375         lastRatio = thisRatio;
376         if (finalCount == MAX_BASELINES) {
377             fprintf(stderr,"Warning: found too many baselines.\n");
378             fprintf(stderr,"Ignoring remaining baselines.\n");
379             break;
380         }
381     }
382

```

```

383
384 /* ----- */
385
386 if (finalCount & 1)
387     --finalCount; /* Only take an even number of lines */
388 for (totalDistance = 0, i = 0, j = 0; i < finalCount; i += 2) {
389     topX = finalCoordx[i];
390     topY = finalCoordy[i];
391     bottomX = finalCoordx[i + 1];
392     bottomY = finalCoordy[i + 1];
393     totalDistance += distance(topX, topY, bottomX, bottomY);
394     j += 2;
395 }
396 averageDistance = totalDistance / (finalCount / 2) * MIN_LINE_HEIGHT_FRACTION;
397 for (i = 0, j = 0; i < finalCount; i += 2) {
398     topX = finalCoordx[i];
399     topY = finalCoordy[i];
400     topIndex = finalIndex[i];
401     bottomX = finalCoordx[i + 1];
402     bottomY = finalCoordy[i + 1];
403     bottomIndex = finalIndex[i + 1];
404     finalCoordx[j] = topX;
405     finalCoordy[j] = topY;
406     finalIndex[j] = topIndex;
407     finalCoordx[j + 1] = bottomX;
408     finalCoordy[j + 1] = bottomY;
409     finalIndex[j + 1] = bottomIndex;
410     if (distance(topX, topY, bottomX, bottomY) > averageDistance)
411         j += 2;
412 }
413 #ifdef foo
414 *count = j;
415 *returnCoordx = finalCoordx;
416 *returnCoordy = finalCoordy;
417 #endif
418 result = nil;
419 for (i = j - 1; i >= 0; --i) {
420     push(MakePoint(finalCoordx[i], finalCoordy[i]), result);
421 }
422
423 if (plotFile != NULL) {
424     fprintf(outfile, "\n0 %f\n", -baseThresh);
425     for (i = 0; i < j; i += 2) {
426         fprintf(outfile, "%d %f\n%d %f\n%d %f\n%d %f\n",
427             finalIndex[i], -baseThresh,
428             finalIndex[i], -2 * baseThresh,
429             finalIndex[i + 1], -2 * baseThresh,
430             finalIndex[i + 1], -baseThresh);
431     }
432     fprintf(outfile, "\"Baselines");
433     fclose(outfile);
434     printf("Done writing baseline plot file.\n");
435 }
436
437 return result;

```

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```
438     }
439
440     void DrawBaseLines(Picture pict, List pointList, double angle)
441     #ifdef foo
442     int count,int *coordx,int *coordy,double angle)
443     #endif
444     {
445         int maxLength;
446         float x2,y2,x3,y3;
447         int x,y;
448         Point temp;
449         maxLength = pict->width + pict->height;
450         while (!endp(pointList)) {
451             temp = pop(pointList);
452             x = temp->x;
453             y = temp->y;
454             x2 = x + maxLength*cos(angle);
455             y2 = y + maxLength*sin(angle);
456             x3 = x - maxLength*cos(angle);
457             y3 = y - maxLength*sin(angle);
458             DrawLine(pict,x,y,(int)x2,(int)y2,0xff);
459             DrawLine(pict,x,y,(int)x3,(int)y3,0xff);
460         }
461     }
```

Aug 25 19:48 1991 newBlobify.c

```

1  #include <stdio.h>
2  #include <math.h>
3  #include "mylib.h"
4  #include "blobify.h"
5
6
7  #define MAX_KERNEL_SIZE (40)
8
9  extern int irint(double);
10
11 static UCHAR bitmasks[] = {0x80,0x40,0x20,0x10,0x8,0x4,0x2,0x1};
12
13 UCHAR *address(Picture pict,float x,float y)
14 {
15     return pict->data + irint(y)*pict->uchar_width + (irint(x)>>3);
16 }
17
18 UCHAR mask(float x)
19 {
20     static masks[] = {0x80,0x40,0x20,0x10,8,4,2,1};
21     return masks[irint(x)%8];
22 }
23
24 int X(float x)
25 {
26     return irint(x);
27 }
28
29 int Y(float y)
30 {
31     return irint(y);
32 }
33
34 Picture NewBlobify(Picture old,int halfMaskWidth,double threshold,double angle)
35 {
36     Picture new;
37
38     int index;
39     float x,y,xinc,yinc;
40     UCHAR *kernelPtr[MAX_KERNEL_SIZE],*kp[MAX_KERNEL_SIZE];
41     UCHAR kernelMask[MAX_KERNEL_SIZE],km[MAX_KERNEL_SIZE];
42     int kernelX[MAX_KERNEL_SIZE],kernelY[MAX_KERNEL_SIZE];
43     int kx[MAX_KERNEL_SIZE],ky[MAX_KERNEL_SIZE];
44     UCHAR kb[MAX_KERNEL_SIZE];
45     UCHAR *dest;
46     UCHAR dm;
47     int tval,i,j,k,inside;
48     int width,height,ucharWidth,maskWidth;
49
50     if (halfMaskWidth*2+1 > MAX_KERNEL_SIZE)
51         DoError("Blobify: mask is too large.\n",NULL);
52

```


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```

53     tval = irint(threshold*(halfMaskWidth*2+1));
54
55     width = old->width;
56     height = old->height;
57     ucharWidth = old->uchar_width;
58
59     new = new_pict(width,height,1);
60
61     xinc = cos(angle);
62     yinc = sin(angle);
63     index = 0;
64     kernalPtr[index] = address(old,halfMaskWidth,halfMaskWidth);
65     /*
66     kernalX[index] = X(halfMaskWidth);
67     kernalY[index] = Y(halfMaskWidth);
68     */
69     kernalMask[index++] = mask(halfMaskWidth);
70     for (i=0,x=0,y=0;i<halfMaskWidth;++i) {
71         x+=xinc;
72         y+=yinc;
73         kernalPtr[index] = address(old,halfMaskWidth+x,halfMaskWidth+y);
74     /*
75         kernalX[index] = X(halfMaskWidth+x);
76         kernalY[index] = Y(halfMaskWidth+y);
77     */
78         kernalMask[index++] = mask(halfMaskWidth+x);
79         kernalPtr[index] = address(old,halfMaskWidth-x,halfMaskWidth-y);
80     /*
81         kernalX[index] = X(halfMaskWidth-x);
82         kernalY[index] = Y(halfMaskWidth-y);
83     */
84         kernalMask[index++] = mask(halfMaskWidth-x);
85     }
86
87     maskWidth = 2*halfMaskWidth+1;
88
89     for (j=0;j<height-maskWidth;++j) {
90         for (i=0;i<index;++i) {
91             kp[i] = kernalPtr[i]+j*ucharWidth;
92             km[i] = kernalMask[i];
93             kb[i] = *kp[i]++;
94         /*
95             kx[i] = kernalX[i];
96             ky[i] = kernalY[i]+j;
97         */
98         }
99         dest = new->data+(j+halfMaskWidth)*ucharWidth+(halfMaskWidth>>3);
100         dm = mask(halfMaskWidth);
101
102         for (k=0;k<width-maskWidth;++k) {
103             if (dm == 0) {
104                 dm = 0x80;
105                 dest++;
106             }
107             for (i=0,inside=0;i<index;++i) {

```

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```

108         if (km[i] == 0) {
109             km[i] = 0x80;
110             kb[i] = *kp[i] + +;
111         }
112     /*
113         printf("(%d,%d): %d - %x %x -> %x\n",kx[i],ky[i],kb[i]&km[i],kp[i]-1,km[i],kb[i]);
114         kx[i] + +;
115     */
116         if (kb[i]&km[i])
117             + + inside;
118         km[i] >> = 1;
119     }
120     /*
121         printf("%d\n\n",inside);
122     */
123     if (inside > tval)
124         *dest |= dm;
125     dm >> = 1;
126 }
127 }
128 }
129
130 return new;
131
132 }
133
134 #ifdef TRYMAIN
135 void main(argc,argv)
136 int argc;
137 char **argv;
138 {
139     char *infile,*outfile;
140     Picture old,new;
141     int halfMaskSize;
142     float threshold;
143     float angle;
144
145     DefArg("%s %s %d %f %f", "infile outfile halfMaskSize threshold angle",
146           &infile,&outfile,&halfMaskSize,&threshold,&angle);
147     ScanArgs(argc,argv);
148
149     printf("Loading %s...",infile);
150     old = load_pict(infile);
151     new = NewBlobify(old,halfMaskSize,threshold,angle);
152     write_pict(outfile,new);
153 }
154 #endif

```

Aug 15 06:41 1991 newContour.c

```

1  #include <stdio.h>
2  #include <values.h>
3  #include <math.h>
4  #include "boolean.h"
5  #include "types.h"
6  #include "pict.h"
7  #include "lines.h"
8  #include "lists.h"
9  #include "dict.h"
10 #include "diff.h"
11 #include "fontNorm.h"
12
13 extern Picture thePict; /* Picture used for annotated shapes */
14
15 /* The following are misc. definitions and routines having to do with
16  * vectors and coordinates. */
17
18 typedef struct {
19     double x;
20     double y;
21 } DPointBody, *DPoint;
22
23
24 static double Dot(DPoint a, DPoint b)
25 {
26     /* printf("Dot: (%lf,%lf)*(%lf,%lf) = %lf\n",a->x,a->y,b->x,b->y,a->x*b->x +
27        a->y*b->y); */
28     return a->x*b->x + a->y*b->y;
29 }
30
31 static DPoint PolarToCartesian(double angle, double radius)
32 {
33     DPoint result = (DPoint)calloc(1, sizeof(DPointBody));
34     if (result == NULL)
35         DoError("Dot: cannot allocate space\n");
36     result->x = cos(angle);
37     result->y = sin(angle);
38     return result;
39 }
40
41 static DPoint Normal(DPoint a)
42 {
43     DPoint result = (DPoint)calloc(1, sizeof(DPointBody));
44     if (result == NULL)
45         DoError("Dot: cannot allocate space\n");
46     result->x = -a->y;
47     result->y = a->x;
48     return result;
49 }
50
51

```

```

52  /* This piston scans pict up and down from the top and bottom of the
53  * bounding box, looking for the highest and lowest pixels in the
54  * word. If thePict is not NULL, these pixels will be colored as 4
55  * in thePict. */
56  static int startX;
57  static int startY;
58  static double stopDistance;
59  static int lastY;
60  static BOOLEAN valid;
61  BOOLEAN TracePiston(Picture pict, int x, int y, BOOLEAN test, UCHAR color)
62  {
63      double distance;
64      if (test) {
65          distance = sqrt((double)(startX-x)*(startX-x) + (startY-y)*(startY-y));
66          if (distance < stopDistance) {
67              /* lastY = stopDistance - distance; */
68              lastY = distance;
69
70              if (ReadPixel(pict,x,y)) {
71
72                  if (thePict)
73                      WritePixel(thePict,x,y,4);
74
75                  valid = TRUE;
76                  return FALSE;
77              } else {
78                  valid = FALSE;
79                  return test;
80              }
81          }
82          else {
83              if (thePict)
84                  WritePixel(thePict,x,y,4);
85          }
86          #ifdef foo
87              lastY = distance; /**** Used to be 0 *****/
88          #endif
89          lastY = HIT_THE_BOX;
90          valid = FALSE;
91          return FALSE;
92      }
93      return test;
94  }
95
96
97  /* This piston moves from left to right across a bounding box, calling
98  * trace piston and saving its output in topY, baseY, and bothX. */
99  #define MAX_SHELL_LENGTH 400
100 static int numberOfLegs;
101 static int topY[MAX_SHELL_LENGTH];
102 static int baseY[MAX_SHELL_LENGTH];
103 static int bothX[MAX_SHELL_LENGTH];
104
105 static double leftDistance;
106 static DPoint lineVector;

```

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```

107 static int downX;
108 static int downY;
109 static double boxTopDistance;
110 static double boxBaseDistance;
111 BOOLEAN ShellPiston(Picture pict, int x, int y, BOOLEAN test, UCHAR color)
112 {
113     int xDistance;
114     DPointBody thisPoint;
115     if (test) {
116         if (numberOfLegs >= MAX_SHELL_LENGTH)
117             return FALSE;
118         thisPoint.x = x;
119         thisPoint.y = y;
120         xDistance = Dot(&thisPoint, lineVector) - leftDistance;
121         stopDistance = boxTopDistance;
122         startX = x;
123         startY = y;
124         LineEngine(pict, x, y, x + downX, y + downY, 0, TracePiston);
125         bothX[numberOfLegs] = xDistance;
126         if (valid)
127             topY[numberOfLegs] = lastY;
128         else
129             topY[numberOfLegs] = HIT_THE_BOX;
130
131         stopDistance = boxBaseDistance;
132         startX = x + downX;
133         startY = y + downY;
134         LineEngine(pict, x + downX, y + downY, x, y, 0, TracePiston);
135         if (valid)
136             baseY[numberOfLegs] = lastY;
137         else
138             baseY[numberOfLegs] = HIT_THE_BOX;
139         numberOfLegs++;
140     }
141     return test;
142 }
143
144
145 /* This function, finds the upper and lower contours corresponding
146    * to a word within a bounding box. */
147 void MakeShell(Picture pict, Box box,
148               Dictionary dict, int dictEntry)
149 {
150     DPoint normalVector;
151     DPointBody temp;
152     double boxTop, boxBase;
153     int rightX, rightY;
154
155     lineVector = PolarToCartesian(box->angle, 1);
156     normalVector = Normal(lineVector);
157     temp.x = box->x;
158     temp.y = box->y;
159     boxTop = Dot(&temp, normalVector);
160     box->pageY = irlint(boxTop);
161     boxBase = boxTop + box->height;

```

```

162
163
164 /* CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE */
165     boxTopDistance = boxBase - boxTop;
166     boxBaseDistance = boxBase - boxTop;
167 /* CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE */
168
169     downX = box->height*cos(box->angle + M_PI/2);
170     downY = box->height*sin(box->angle + M_PI/2);
171
172     rightX = box->width*cos(box->angle);
173     rightY = box->width*sin(box->angle);
174
175     numberOfLegs = 0;
176     leftDistance = Dot(&temp,lineVector);
177     box->pageX = irint(leftDistance);
178     #ifdef foo
179         malloc_verify();
180     #endif
181     LineEngine(pict,box->x,box->y,
182               box->x + rightX,box->y + rightY,0,
183               ShellPiston);
184
185 /* CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE */
186 {
187     int i;
188     for (i=0;i<numberOfLegs; ++i) {
189         if (*(topY+i)!=HIT_THE_BOX)
190             *(topY+i) += boxTop;
191         if (*(baseY+i)!=HIT_THE_BOX)
192             *(baseY+i) = boxBase - *(baseY+i);
193     }
194 }
195 /* CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE CHANGE */
196
197     #ifdef foo
198         malloc_verify();
199     #endif
200     StoreRawOutlinePair(dict,dictEntry,box,bothX,topY,
201                       baseY,numberOfLegs);
202 }
203
204 BOOLEAN OnABaseLine(Box box,List baseLinePoints)
205 {
206     DPoint lineVector,normalVector;
207     DPointBody temp;
208     double boxTop,boxBase,top,base;
209     Point topPoint, basePoint;
210
211     lineVector = PolarToCartesian(box->angle,1);
212     normalVector = Normal(lineVector);
213     temp.x = box->x;
214     temp.y = box->y;
215     boxTop = Dot(normalVector,&temp);
216     boxBase = boxTop + box->height;

```

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```

217
218 while (lendp(baseLinePoints)) {
219     topPoint = pop(baseLinePoints);
220     basePoint = pop(baseLinePoints);
221     temp.x = topPoint->x;
222     temp.y = topPoint->y;
223     top = Dot(normalVector,&temp);
224     temp.x = basePoint->x;
225     temp.y = basePoint->y;
226     base = Dot(normalVector,&temp);
227
228     if ((boxTop >= top && boxTop <= base) || /* box top is between */
229         (boxBase >= top && boxBase <= base) || /* box bottom is between */
230         (top >= boxTop && top <= boxBase)) /* both lines inside box */
231         return TRUE;
232     }
233     return FALSE;
234 }
235
236 BOOLEAN BoxToShell(Picture pict,Box box,List baseLinePoints,
237                   Dictionary dict,int dictEntry)
238 {
239     Point topPoint,bottomPoint;
240
241     if (OnABaseLine(box,baseLinePoints)) {
242         MakeShell(pict,box,dict,dictEntry);
243         return TRUE;
244     }
245     else
246         return FALSE;
247 }
248
249 #define MAX_SHAPES 1000
250 void BarBoxList(Picture pict,List boxList,List baseLinePoints,
251                char *filename,char *infoString, NormalizationDescriptor *nd)
252 {
253     Dictionary dict;
254     int count = 0;
255     long int location;
256
257     dict = NewDict(MAX_SHAPES);
258     dict->InfoString = infoString;
259
260     while (lendp(boxList)) {
261 #ifdef foo
262         if (BoxToShell(pict,
263                       (Box)pop(boxList),
264                       baseLinePoints,
265                       dict,
266                       count))
267             ++count;
268 #endif
269     }
270     /* Change 8/8/91
271     * All boxes are stored in the dictionary.
272     * The post processing stage in newFontNorm.c will weed out boxes */

```

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```
272     MakeShell(pict,(Box)pop(boxList),dict,count);
273     ++count;
274     /* End of change 8/8/91 */
275     if (count >= MAX_SHAPES) {
276         printf("Maximum dictionary size exceeded.\n");
277         printf("Ignoring rest of shapes.\n");
278         break;
279     }
280 }
281 dict->numberOfEntries = count;
282 PageStatistics(dict,"statistics",nd);
283 /* PostProcess(dict); */
284 WriteDictionary(dict,filename);
285 }
286
```


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Jan 11 17:07 1991 newDiff2.c

```

1  #include <stdio.h>
2  #include "boolean.h"
3  #include "types.h"
4  #include "error.h"
5  #include "pict.h"
6  #include "dict.h"
7  #include "diff.h"
8
9  /* Given the names of two dictionary files, compute the squared difference
10 * between every pair of shapes in the cross product of the dictionaries.
11 * The result is a matrix printed to stdout. The width and height are
12 * followed by the matrix entries in row major order. The output is in
13 * ascii to facilitate reading by a Symbolics. */
14 Picture CompareDictionaries(char *file1,char *file2)
15 {
16     Dictionary dict1,dict2;
17     Picture pict;
18     int x,y;
19     dict1 = ReadDictionary(file1); /* height */
20     dict2 = ReadDictionary(file2); /* width */
21     pict = new_pict(dict2->numberOfEntries,
22                    dict1->numberOfEntries,
23                    32);
24     for (y=0;y<pict->height; ++y)
25         for (x=0;x<pict->width; ++x) {
26             printf("(%d,%d) ",y,x);
27             *(((float *)pict->data) + pict->width*y + x) =
28                 DiffPair(*(dict1->outlines + y),
29                         *(dict2->outlines + x));
30         }
31     return pict;
32 }
33
34 void WritePictureAsAscii(Picture pict,char *filename)
35 {
36     FILE *fp;
37     int x,y;
38     int count = 1;
39     if ((fp = fopen(filename,"w")) == NULL)
40         DoError("WritePictureAsAscii: error opening output file\n",NULL);
41     fprintf(fp,"%d\n%d\n",pict->width,pict->height);
42     for (y=0;y<pict->height; ++y)
43         for (x=0;x<pict->width; ++x) {
44             fprintf(fp,"%f " ,*(((float *)pict->data) + ++));
45             if (!((count++)%5))
46                 fprintf(fp,"\n");
47         }
48     fprintf(fp,"\n");
49     fclose(fp);
50 }

```

Aug 26 17:20 1991 newMain.c

```

1  #include <stdio.h>
2  #include <values.h>
3  #include <math.h>
4  #include "misc.h"
5  #include "boolean.h"
6  #include "error.h"
7  #include "types.h"
8  #include "pict.h"
9  #include "lists.h"
10 #include "lines.h"
11 #include "orient.h"
12 #include "baselines.h"
13 #include "blobify.h"
14 #include "boxes.h"
15 #include "dict.h"
16 #include "diff.h"
17 #include "newContour.h"
18 #include "numbers.h"
19
20 #define TRY
21 #ifdef TRY
22 Picture thePict;
23 #endif
24
25 void DrawMiddleLines(Picture pict,List pointList, double angle)
26 {
27     int maxLength;
28     int xc,yc,xBot,xTop,yBot,yTop;
29     Point temp;
30     float x2,y2,x3,y3;
31     int i,len;
32     maxLength = pict->width+pict->height;
33     len = ListLength(pointList);
34     pop(pointList);
35     for (i=1;i<len-1;i+=2) {
36         temp = pop(pointList);
37         xTop = temp->x;
38         yTop = temp->y;
39         temp = pop(pointList);
40         xBot = temp->x;
41         yBot = temp->y;
42         xc = (xBot+xTop)/2;
43         yc = (yBot+yTop)/2;
44         x2 = xc+maxLength*cos(angle);
45         y2 = yc+maxLength*sin(angle);
46         x3 = xc-maxLength*cos(angle);
47         y3 = yc-maxLength*sin(angle);
48         DrawLine(pict,xc,yc,(int)x2,(int)y2,0);
49         DrawLine(pict,xc,yc,(int)x3,(int)y3,0);
50     }
51 }
52

```

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```

53 void DrawBoxList(Picture pict,List boxList)
54 {
55     while (!endp(boxList)) {
56         DrawBox(pict,(Box)pop(boxList));
57     }
58 }
59
60 void LabelShapes(Picture pict,Dictionary dict)
61 {
62     int i;
63     Box box;
64
65     for (i=0;i<dict->numberOfEntries;+ +i) {
66         box = (*(dict->outlines+i))->box;
67         DrawColorBox(pict,box,3);
68         DrawNumber(pict,box->x,box->y,2,(float)box->height/2,i);
69     }
70 }
71
72 double FixAngle(double angle)
73 {
74     if (angle > M_PI/2 && angle < 1.5*M_PI)
75         return angle-M_PI;
76     else
77         return angle;
78 }
79
80 int ScanIntArg(int argc,char **argv,int index)
81 {
82     if (index<argc)
83         return atoi(argv[index]);
84     else
85         DoError("Expected an integer argument\n",NULL);
86 }
87
88 float ScanFloatArg(int argc,char **argv,int index)
89 {
90     if (index<argc)
91         return atof(argv[index]);
92     else
93         DoError("Expected a floating point argument\n",NULL);
94 }
95
96 char *ScanStringArg(int argc,char **argv,int index)
97 {
98     if (index<argc)
99         return argv[index];
100     else
101         DoError("Expected a string argument\n",NULL);
102 }
103
104 void main(argc,argv)
105 int argc;
106 char **argv;
107 {

```

```

108 char *infile;
109 int coarseDirections,coarseSamples,fineDirections,fineSamples;
110 Picture pict,newPict,finalPict;
111 float coarseAngle,mediumAngle,fineAngle;
112 float coarseError,mediumError,fineError;
113 List baselines,boxList;
114 int maskWidth;
115 float blobThreshold;
116 int i;
117 char *shapesFile,*drawBaselinesFile;
118 char *drawBoxesFile,*plotFile,*plotOrientFile;
119 char *drawColorBoxesFile,*drawBlobsFile;
120 char *flag;
121 BOOLEAN doOrientation,doBaselines,doBoxes,doShapes,drawBaselines,drawBoxes;
122 BOOLEAN plotBaselines,plotOrientation,drawColorBoxes,drawBlobs;
123 BOOLEAN
noXHeightNorm,noAscenderNorm,dontOrientation,doBlobThreshold,doMaskWidth;
124 NormalizationDescriptor nd;
125
126 DefArg("%s","infile",&infile);
127 DefOption("-orientation %f","-orientation (page orientation in radians)",
128     &dontOrientation,&fineAngle);
129 DefOption("-findOrientation","-findOrientation",&doOrientation);
130 DefOption("-plotOrientation %s","-plotOrientation (file top plot xgraph format image
to)",
131     &plotOrientation,&plotOrientFile);
132 DefOption("-maskWidth %d","-maskWidth (integer half mask width)",
133     &doMaskWidth,&maskWidth);
134 DefOption("-blobThreshold %f","-blobThreshold (float on/off threshold)",
135     &doBlobThreshold,&blobThreshold);
136 DefOption("-drawBlobs %s","-drawBlobs (file to output image
to",&drawBlobs,&drawBlobsFile);
137 DefOption("-drawBaselines %s","-drawBaselines (file to output image
to",&drawBaselines,
138     &drawBaselinesFile);
139 DefOption("-plotBaselines %s","-plotBaselines (file to plot xgraph format baselines to)",
140     &plotBaselines,&plotFile);
141 DefOption("-drawBoxes %s","-drawBoxes (file to output image
to",&drawBoxes,&drawBoxesFile);
142 DefOption("-shapeFunctions %s","-shapeFunctions (file to output shape functions to)",
143     &doShapes,&shapesFile);
144 DefOption("-annotatedShapes %s","-annotatedShapes (file to output image to)",
145     &drawColorBoxes,&drawColorBoxesFile);
146 DefOption("-noAscenderNorm","-noAscenderNorm",&noAscenderNorm);
147 DefOption("-noXHeightNorm","-noXHeightNorm",&noXHeightNorm);
148
149 i = 2;
150 coarseDirections = 72;
151 coarseSamples = 400;
152 fineDirections = 40;
153 fineSamples = 10;
154 maskWidth = 3;
155 blobThreshold = 0.01;
156
157 ScanArgs(argc,argv);

```

```

158     if (dontOrientation)
159         doOrientation = FALSE;
160
161     nd.noXHeightNormalize = noXHeightNorm;
162     nd.noAscenderNormalize = noAscenderNorm;
163
164     printf("Loading %s... \n",infile);
165     pict = load_pict(infile);
166     if (pict->depth != 1)
167         DoError("error: only depth 1 is supported\n",NULL);
168
169     if (drawBaselines || drawBoxes)
170         finalPict = new_pict(pict->width,pict->height,pict->depth);
171
172     if (doOrientation) {
173         #define NUMBER_OF_ANGLES 180
174         #define SAMPLES_PER_ANGLE 10
175         #define BIN_ERROR 4
176         printf("Finding coarse orientation.\n");
177         coarseAngle = NewFine(pict,SAMPLES_PER_ANGLE,NUMBER_OF_ANGLES,
178                               0,M_PI,NULL);
179         coarseError = (M_PI-0)/NUMBER_OF_ANGLES;
180         printf("Coarse angle: %f(%f)\n",coarseAngle,coarseAngle/M_PI*180);
181         printf("Coarse error: %f(%f)\n",coarseError,coarseError/M_PI*180);
182
183         mediumAngle = NewFine(pict,SAMPLES_PER_ANGLE,NUMBER_OF_ANGLES,
184                               coarseAngle-BIN_ERROR*coarseError,
185                               coarseAngle+BIN_ERROR*coarseError,
186                               NULL);
187         mediumError = 2*BIN_ERROR*coarseError/NUMBER_OF_ANGLES;
188         printf("Medium angle: %f(%f)\n",mediumAngle,mediumAngle/M_PI*180);
189         printf("Medium error: %f(%f)\n",mediumError,mediumError/M_PI*180);
190
191         fineAngle = NewFine(pict,SAMPLES_PER_ANGLE,NUMBER_OF_ANGLES,
192                               mediumAngle-15*mediumError,mediumAngle+15*mediumError,
193                               plotOrientFile);
194         fineError = 30*mediumError/NUMBER_OF_ANGLES;
195         fineAngle = FixAngle(fineAngle);
196         printf("Fine angle: %f(%f)\n",fineAngle,fineAngle/M_PI*180);
197         printf("Fine error: %f(%f)\n",fineError,fineError/M_PI*180);
198     }
199
200     printf("Adjusted angle: %lf\n",fineAngle);
201
202     #ifdef foo
203     printf("Finding baselines\n");
204     baselines = Baselines(pict,fineAngle,plotBaselines?plotFile:NULL);
205
206     if (drawBaselines) {
207         CopyPicture(finalPict,pict);
208         DrawBaseLines(finalPict,baselines,fineAngle);
209         write_pict(drawBaselinesFile,finalPict);
210     }
211
212

```

```

213     printf("Blobifying\n");
214     newPict = Blobify(pict,maskWidth,blobThreshold);
215     #endif
216     printf("NewBlobify\n");
217     /* newPict = NewBlobify(pict,maskWidth,blobThreshold,fineAngle); */
218     newPict = Blobify(pict,maskWidth,blobThreshold);
219     printf("Finding baselines\n");
220     baselines = BaseLines(newPict,fineAngle,plotBaselines?plotFile:NULL);
221     if (drawBaselines) {
222         CopyPicture(finalPict,pict);
223         DrawBaseLines(finalPict,baselines,fineAngle);
224         write_pict(drawBaselinesFile,finalPict);
225     }
226
227
228     DrawMiddleLines(newPict,baselines,fineAngle);
229     if (drawBlobs)
230         write_pict(drawBlobsFile,newPict);
231     printf("Finding boxes\n");
232     boxList = FindBorders(newPict,fineAngle);
233
234     if (drawBoxes) {
235         CopyPicture(finalPict,pict);
236         DrawBoxList(finalPict,boxList);
237         write_pict(drawBoxesFile,finalPict);
238     }
239
240     if (doShapes) {
241         ColorMap cmap;
242         int x,y;
243
244         if (drawColorBoxes) {
245             thePict = new_pict(pict->width,pict->height,8);
246             cmap = NewColorMap(6); /* black, white, and 16 colors */
247             WriteColorValue(cmap,0,0,128,0); /* Olive */
248             WriteColorValue(cmap,1,0,0,0); /* Black */
249             WriteColorValue(cmap,2,255,255,255); /* White */
250             WriteColorValue(cmap,3,0,0,255); /* Blue */
251             WriteColorValue(cmap,4,255,255,80); /* Yellow */
252             WriteColorValue(cmap,5,128,0,0); /* Blood */
253             thePict->cmap = cmap;
254             for (y=0;y<pict->height; ++y)
255                 for (x=0;x<pict->width; ++x)
256                     WritePixel(thePict,x,y,ReadPixel(pict,x,y)?0:1);
257         }
258         else
259             thePict = NULL; /* Important */
260
261         printf("Tracing outlines\n");
262         BarBoxList(pict,boxList,baselines,shapesFile,ArgListToString(argc,argv),&nd);
263
264         if (drawColorBoxes) {
265             Dictionary dict;
266
267             dict = ReadDictionary(shapesFile);

```

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```
268     LabelShapes(thePict,dict);
269     write_pict(drawColorBoxesFile,thePict);
270 }
271 }
272 }
```

Jan 11 17:07 1991 numbers.c

```

1  #include "stdio.h"
2  #include "boolean.h"
3  #include "pict.h"
4  #include "lines.h"
5
6  static float localScale;
7  static int localColor;
8  static int localX;
9  static int localY;
10 static Picture localPict;
11
12 void DrawSegment(float y1, float x1, float y2, float x2)
13 {
14     DrawLine(localPict, irtint(localX + x1*localScale),
15             irtint(localY + y1*localScale),
16             irtint(localX + x2*localScale),
17             irtint(localY + y2*localScale), localColor);
18 }
19
20 void Draw0(Picture pict, int x, int y, int color, float scale)
21 {
22     localPict = pict;
23     localScale = scale;
24     localColor = color;
25     localX = x;
26     localY = y;
27     DrawSegment(0,0,0,1);
28     DrawSegment(1,0,1,1);
29     DrawSegment(0,0,1,0);
30     DrawSegment(0,1,1,1);
31 }
32
33 void Draw1(Picture pict, int x, int y, int color, float scale)
34 {
35     localPict = pict;
36     localScale = scale;
37     localColor = color;
38     localX = x;
39     localY = y;
40     DrawSegment(0,0.5,1,.5);
41 }
42
43 void Draw2(Picture pict, int x, int y, int color, float scale)
44 {
45     localPict = pict;
46     localScale = scale;
47     localColor = color;
48     localX = x;
49     localY = y;
50     DrawSegment(0,0,0,1);
51     DrawSegment(0,1,.5,1);
52     DrawSegment(.5,1,.5,0);

```


Section D

```

53     DrawSegment(.5,0,1,0);
54     DrawSegment(1,0,1,1);
55 }
56
57 void Draw3(Picture pict, int x, int y, int color,float scale)
58 {
59     localPict = pict;
60     localScale = scale;
61     localColor = color;
62     localX = x;
63     localY = y;
64     DrawSegment(0,0,0,1);
65     DrawSegment(0,1,1,1);
66     DrawSegment(1,0,1,1);
67     DrawSegment(.5,0,.5,1);
68 }
69
70 void Draw4(Picture pict, int x, int y, int color,float scale)
71 {
72     localPict = pict;
73     localScale = scale;
74     localColor = color;
75     localX = x;
76     localY = y;
77     DrawSegment(0,0,.5,0);
78     DrawSegment(0,1,1,1);
79     DrawSegment(.5,0,.5,1);
80 }
81
82 void Draw5(Picture pict, int x, int y, int color,float scale)
83 {
84     localPict = pict;
85     localScale = scale;
86     localColor = color;
87     localX = x;
88     localY = y;
89     DrawSegment(0,0,0,1);
90     DrawSegment(0,0,.5,0);
91     DrawSegment(.5,1,.5,0);
92     DrawSegment(.5,1,1,1);
93     DrawSegment(1,0,1,1);
94 }
95
96 void Draw6(Picture pict, int x, int y, int color,float scale)
97 {
98     localPict = pict;
99     localScale = scale;
100    localColor = color;
101    localX = x;
102    localY = y;
103    DrawSegment(0,0,0,1);
104    DrawSegment(0,0,1,0);
105    DrawSegment(.5,1,.5,0);
106    DrawSegment(.5,1,1,1);
107    DrawSegment(1,0,1,1);

```

```

108     }
109
110 void Draw7(Picture pict, int x, int y, int color, float scale)
111 {
112     localPict = pict;
113     localScale = scale;
114     localColor = color;
115     localX = x;
116     localY = y;
117     DrawSegment(0,0,0,1);
118     DrawSegment(0,1,1,1);
119 }
120
121 void Draw8(Picture pict, int x, int y, int color, float scale)
122 {
123     localPict = pict;
124     localScale = scale;
125     localColor = color;
126     localX = x;
127     localY = y;
128     DrawSegment(0,0,0,1);
129     DrawSegment(0,0,1,0);
130     DrawSegment(1,0,1,1);
131     DrawSegment(.5,1,.5,0);
132     DrawSegment(0,1,1,1);
133 }
134
135 void Draw9(Picture pict, int x, int y, int color, float scale)
136 {
137     localPict = pict;
138     localScale = scale;
139     localColor = color;
140     localX = x;
141     localY = y;
142     DrawSegment(0,0,0,1);
143     DrawSegment(.5,0,.5,1);
144     DrawSegment(0,0,.5,0);
145     DrawSegment(0,1,1,1);
146 }
147
148 typedef void DrFct(Picture pict, int x, int y, int color, float scale);
149
150 DrFct *DrawFunctions[] = {Draw0,Draw1,Draw2,Draw3,Draw4,Draw5,Draw6,
151                           Draw7,Draw8,Draw9};
152
153 void DrawNumeral(Picture pict, int x, int y, int color, float scale, int n)
154 {
155     (*DrawFunctions[n])(pict,x,y,color,scale);
156 }
157
158 void DrawNumber(Picture pict, int x, int y, int color, float scale, int n)
159 {
160     char s[100];
161     char *ptr;
162

```

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```
163     sprintf(s, "%d", n);
164     ptr = s;
165     while (*ptr != '\0') {
166         DrawNumeral(pict, x, y, color, scale, *ptr - '0');
167         x += irlint(scale * 1.5);
168         ptr++;
169     }
170 }
171
172 #ifdef TRYMAIN
173 main()
174 {
175     Picture pict;
176     pict = new_pict(400, 200, 1);
177     DrawNumber(pict, 50, 50, 1, 20, 12345);
178     DrawNumber(pict, 50, 100, 1, 10, 67890);
179     write_pict("junkfile.image", pict);
180 }
181 #endif
```

Jul 2 18:48 1991 orient.c

```

1  #include <stdio.h>
2  #include <values.h>
3  #include <math.h>
4  #include "misc.h"
5  #include "boolean.h"
6  #include "pict.h"
7  #include "orient.h"
8  #include "lines.h"
9
10
11  #define ABS(x) (((x)<0)?-(x):(x))
12
13  extern long random();
14
15  int RandomCoordinate(int maxValue)
16  {
17      return (float)(random()&0xffff)*maxValue/0xffff;
18  }
19
20  void RandomEdgePixel(Picture pict,int *x, int *y)
21  {
22      while (TRUE) {
23          *x = RandomCoordinate(pict->width);
24          *y = RandomCoordinate(pict->height);
25          if (ReadPixel(pict,*x,*y))
26              if (! (ReadPixel(pict,*x+1,*y) &&
27                  ReadPixel(pict,*x-1,*y) &&
28                  ReadPixel(pict,*x,*y+1) &&
29                  ReadPixel(pict,*x,*y-1) &&
30                  ReadPixel(pict,*x+1,*y+1) &&
31                  ReadPixel(pict,*x-1,*y-1) &&
32                  ReadPixel(pict,*x+1,*y-1) &&
33                  ReadPixel(pict,*x-1,*y+1)))
34              return;
35      }
36  }
37
38
39  /* #define SYMTHRESH 4 */
40  #define SYMTHRESH 0.17453278
41  BOOLEAN FindBestMin(float *distances, int coarseDirections, float step,
42                      float *orientation)
43  {
44      int i, minIndex, min2Index;
45      int orientationError;
46      float minValue, min2Value;
47      int maxBinError = rint(SYMTHRESH / step);
48
49      minIndex = 0;
50      minValue = distances[0];
51      for (i=0; i<coarseDirections; ++i)
52          if (distances[i] < minValue) {

```

```

53     minValue = distances[i];
54     minIndex = i;
55 }
56 /* Now verify that there is another minima M_PI away */
57
58 min2Index = (minIndex + coarseDirections/4)%coarseDirections;
59 min2Value = distances[min2Index];
60 for (i=0,j=min2Index;i<coarseDirections/2; ++i,j = (j+1)%coarseDirections)
61     if (distances[j]<min2Value) {
62         min2Value = distances[j];
63         min2Index = j;
64     }
65 orientationError = ABS((min2Index-minIndex)%coarseDirections) -
66     coarseDirections/2;
67 orientationError = ABS(orientationError);
68 if (orientationError<maxBinError) {
69     *orientation = minIndex*step;
70     return TRUE;
71 } else {
72     printf("Orientation error: %d %3.3f\n",orientationError,
73         orientationError*step/M_PI/2*360);
74     printf("%3.3f: %3.3f %3.3f: %3.3f\n",minIndex*step,minValue,
75         min2Index*step,min2Value);
76     return FALSE;
77 }
78 }
79
80 float Fine(Picture pict,int fineSamples,int fineDirections,
81     int coarseDirections, float coarseAngle, char *plotFile)
82 {
83     float coarseError;
84     int x,y;
85     float x2,y2;
86     int i,j;
87     float *counters;
88     float step,angle;
89     float maxAngle;
90     float maxValue;
91     float maxLength;
92     FILE *outfile;
93
94     counters = (float *)calloc(fineDirections,sizeof(float));
95     if (counters == NULL) {
96         printf("Fine: cannot allocate memory\n");
97         exit(-1);
98     }
99     /* coarseError = 2*(SYMTHRESH + 1)*2*M_PI/coarseDirections; */
100     coarseError = 2*SYMTHRESH;
101     step = coarseError/fineDirections;
102     printf("fine: +/- %3.3f\n",fineDirections/2*step);
103
104     maxLength = sqrt((double)(pict->width*pict->width +
105         pict->height*pict->height));
106     for (i=0;i<fineSamples; ++i) {
107         RandomEdgePixel(pict,&x,&y);

```

```

108     angle = -fineDirections/2*step + coarseAngle;
109     for (j=0;j<fineDirections; ++j,angle += step) {
110         x2 = x + maxLength*cos(angle);
111         y2 = y + maxLength*sin(angle);
112         counters[j] += CountLine(pict,x,y,(int)x2,(int)y2);
113     }
114 }
115
116     angle = -fineDirections/2*step + coarseAngle;
117     maxAngle = angle;
118     maxValue = counters[0];
119     for (i=0;i<fineDirections; ++i,angle += step) {
120         /* printf("%3.3f: %3.3f\n",angle,counters[i]); */
121         if (counters[i]>maxValue) {
122             maxAngle = angle;
123             maxValue = counters[i];
124         }
125     }
126
127     /* Plot the orientation graph if requested */
128     angle = -fineDirections/2*step + coarseAngle;
129     if (angle < 0)
130         angle += 2*M_PI;
131     if (plotFile!=NULL) {
132         printf("Opening fine orientation plot file\n");
133         if ((outfile = fopen(plotFile,"a"))==NULL) {
134             printf("Error opening fine orientation plot file.\n");
135             exit(-1);
136         }
137         for (i=0;i<fineDirections; ++i,angle += step)
138             fprintf(outfile,"%f %f\n",fmod(angle,2*M_PI),counters[i]);
139         fprintf(outfile,"\n\"Fine Distances\"\n\n");
140         fclose(outfile);
141         printf("Done writing fine orientation plot file.\n");
142     }
143
144
145     return maxAngle;
146 }
147
148 float NewFine(Picture pict,int fineSamples, int fineDirections,
149               float angleStart,float angleEnd, char *plotFile)
150 {
151     int x,y;
152     float x2,y2;
153     int i,j;
154     float *counters;
155     float step,angle;
156     float maxAngle;
157     float maxValue;
158     float maxLength;
159     FILE *outfile;
160
161     counters = (float *)calloc(fineDirections,sizeof(float));
162     if (counters == NULL) {

```

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```

163     printf("Fine: cannot allocate memory\n");
164     exit(-1);
165 }
166
167     step = ABS(angleEnd - angleStart)/fineDirections;
168
169     maxLength = sqrt((double)(pict->width*pict->width +
170                             pict->height*pict->height));
171     for (i=0; i<fineSamples; ++i) {
172         RandomEdgePixel(pict,&x,&y);
173         angle = angleStart;
174         for (j=0; j<fineDirections; ++j) {
175             angle = fmod(angle,2*M_PI);
176             x2 = x + maxLength*cos(angle);
177             y2 = y + maxLength*sin(angle);
178             counters[j] += CountLine(pict,x,y,(int)x2,(int)y2);
179             angle += step;
180         }
181     }
182
183     angle = angleStart;
184     maxAngle = angle;
185     maxValue = counters[0];
186     for (i=0; i<fineDirections; ++i) {
187         angle = fmod(angle,2*M_PI);
188         if (counters[i] > maxValue) {
189             maxAngle = angle;
190             maxValue = counters[i];
191         }
192         angle += step;
193     }
194     printf("Orientation is at %f(%f)\n",maxAngle,maxAngle/2/M_PI*360);
195
196     /* Plot the orientation graph if requested */
197     if (plotFile) {
198         printf("Opening fine orientation plot file\n");
199         if ((outfile = fopen(plotFile,"w")) == NULL) {
200             printf("Error opening fine orientation plot file.\n");
201             exit(-1);
202         }
203         angle = angleStart;
204         for (i=0; i<fineDirections; ++i) {
205             angle = fmod(angle,2*M_PI);
206             fprintf(outfile,"%f %f\n",angle,counters[i]);
207             angle += step;
208         }
209         fprintf(outfile,"\nFine Distances\n\n");
210         fclose(outfile);
211         printf("Done writing fine orientation plot file.\n");
212     }
213     return maxAngle;
214 }
215

```

Jan 15 15:22 1991 overlay.c

```

1  #include <stdio.h>
2  #include <math.h>
3  #include "boolean.h"
4  #include "pict.h"
5
6  main(argc, argv)
7  int argc;
8  char *argv[];
9  {
10     char *inFile1,*inFile2,*outFile;
11     Picture pict1,pict2,finalPict;
12     ColorMap cmap;
13     int x,y;
14
15     if (argc != 4)
16     {
17         printf("\nUsage: %s infile1 infile2 outfile\n\n",
18             argv[0]);
19         exit(0);
20     }
21
22     inFile1 = argv[1]; /* get args */
23     inFile2 = argv[2];
24     outFile = argv[3];
25
26     pict1 = load_pict(inFile1);
27     pict2 = load_pict(inFile2);
28     if ((pict1->depth != 1) || (pict2->depth != 1))
29         DoError("overlay: only depth 1 supported.\n",NULL);
30     if ((pict1->width != pict2->width) || (pict1->height != pict2->height))
31         DoError("overlay: images must be the same size\n",NULL);
32
33     finalPict = new_pict(pict1->width,pict1->height,8);
34     cmap = NewColorMap(3);
35     WriteColorValue(cmap,0,0,0); /* Black */
36     WriteColorValue(cmap,1,0,128); /* Olive */
37     WriteColorValue(cmap,2,0,255); /* Green */
38     finalPict->cmap = cmap;
39
40     for (y=0;y<pict1->height; ++ y)
41         for (x=0;x<pict1->width; ++ x)
42             if (ReadPixel(pict1,x,y))
43                 WritePixel(finalPict,x,y,2);
44             else if (ReadPixel(pict2,x,y))
45                 WritePixel(finalPict,x,y,1);
46
47     write_pict(outFile,finalPict);
48 }

```


Jul 1 13:45 1991 pagestats.c

```

1  #include <stdio.h>
2  #include <math.h>
3  #include "boolean.h"
4  #include "types.h"
5  #include "error.h"
6  #include "pict.h"
7  #include "dict.h"
8
9  #define UP 0
10 #define DOWN 1
11 typedef int Direction;
12
13 extern Picture thePict;
14
15 void StoreRawOutlinePair(Dictionary dict, int dictEntry,
16                          Box box, int *bothX, int *topY, int *baseY,
17                          int numberOfLegs)
18 {
19     RawOutlinePair temp;
20     int i;
21     int *xCursor, *topCursor, *bottomCursor;
22
23     temp = (RawOutlinePair) calloc(1, sizeof(RawOutlinePairBody));
24     if (temp == NULL)
25         DoError("StoreRawOutlinePair: cannot allocate space\n", NULL);
26
27     temp->box = box;
28     temp->numberOfLegs = numberOfLegs;
29
30     temp->x = (int *) calloc(temp->numberOfLegs, sizeof(int));
31     temp->top = (int *) calloc(temp->numberOfLegs, sizeof(int));
32     temp->bottom = (int *) calloc(temp->numberOfLegs, sizeof(int));
33     if ((temp->x == NULL) ||
34         (temp->top == NULL) ||
35         (temp->bottom == NULL))
36         DoError("StoreRawOutlinePair: cannot allocate space\n", NULL);
37
38     xCursor = temp->x;
39     topCursor = temp->top;
40     bottomCursor = temp->bottom;
41
42     for (i=0; i<numberOfLegs; ++i) {
43         *xCursor++ = *bothX++;
44         *topCursor++ = *topY++;
45         *bottomCursor++ = *baseY++;
46     }
47     *(dict->rawOutlines+dictEntry) = temp;
48 }
49
50 void StoreOutlinePair(Dictionary dict, int dictEntry,
51                       int middleLine, int fontXHeight)
52 {

```

```

53 RawOutlinePair raw;
54 OutlinePair temp;
55 int i,numberOfLegs;
56 int y;
57 int offset;
58 int *xSCursor,*topSCursor,*bottomSCursor;
59 float *xDCursor,*topDCursor,*bottomDCursor;
60 float *xCursor,*topCursor,*bottomCursor;
61 int left,right;
62 float foffset;
63
64 raw = *(dict->rawOutlines+dictEntry);
65
66 temp = (OutlinePair)calloc(1,sizeof(OutlinePairBody));
67 if (temp == NULL)
68     DoError("StoreOutlinePair: cannot allocate space\n",NULL);
69
70 temp->x = (float *)calloc(raw->numberOfLegs,sizeof(float));
71 temp->top = (float *)calloc(raw->numberOfLegs,sizeof(float));
72 temp->bottom = (float *)calloc(raw->numberOfLegs,sizeof(float));
73 if ((temp->x == NULL) ||
74     (temp->top == NULL) ||
75     (temp->bottom == NULL))
76     DoError("StoreOutlinePair: cannot allocate space\n",NULL);
77
78 temp->box = raw->box;
79 temp->blackoutHeight = 0;
80 temp->numberOfLegs = raw->numberOfLegs;
81 offset = temp->offset = *(raw->x);
82 temp->width = *(raw->x+raw->numberOfLegs-1) - temp->offset;
83
84 xDCursor = temp->x;
85 topDCursor = temp->top;
86 bottomDCursor = temp->bottom;
87 xSCursor = raw->x;
88 topSCursor = raw->top;
89 bottomSCursor = raw->bottom;
90
91 numberOfLegs = raw->numberOfLegs;
92 for (i=0;i<numberOfLegs;++i) {
93     *xDCursor++ = (float)(*xSCursor++ - offset)/fontXHeight;
94     y = middleLine - *topSCursor++;
95     if (y<0)
96         y = 0;
97     *topDCursor++ = (float)y / fontXHeight;
98     y = *bottomSCursor++ - middleLine;
99     if (y<0)
100         y = 0;
101     *bottomDCursor++ = (float)y / fontXHeight;
102 }
103
104 /* Now try to remove parts of the contour on to the left and right of the
105    * word shape that are at height 0 */
106
107 topDCursor = temp->top;

```

```

108     bottomDCursor = temp->bottom;
109     for(i=0;i<numberOfLegs; ++i) {
110         if ((*topDCursor++ != 0) || (*bottomDCursor++ != 0))
111             break;
112     }
113     left = i;
114
115     topDCursor = temp->top + numberOfLegs-1;
116     bottomDCursor = temp->bottom + numberOfLegs-1;
117     for(i=numberOfLegs-1; i>=0; --i) {
118         if ((*topDCursor-- != 0) || (*bottomDCursor-- != 0))
119             break;
120     }
121     right = i+1;
122
123     xDCursor = temp->x;
124     topDCursor = temp->top;
125     bottomDCursor = temp->bottom;
126     xCursor = temp->x + left;
127     topCursor = temp->top + left;
128     bottomCursor = temp->bottom + left;
129     foffset = *xSCursor;
130     for(i=left; i<right; ++i) {
131         *xDCursor++ = *xCursor++ - foffset;
132         *topDCursor++ = *topCursor++;
133         *bottomDCursor++ = *bottomCursor++;
134     }
135     temp->numberOfLegs = right-left;
136
137     *(dict->outlines + dictEntry) = temp;
138 }
139
140 static int lineSpacing;
141 int OrderOutlinePair(OutlinePair *o1, OutlinePair *o2)
142 {
143     int yDistance;
144     int xDistance;
145     yDistance = (*o1)->box->pageY - (*o2)->box->pageY;
146     if (yDistance < lineSpacing && yDistance > -lineSpacing) {
147         xDistance = (*o1)->box->pageX - (*o2)->box->pageX;
148         return xDistance;
149     }
150     return yDistance;
151 }
152
153 void SortDictionary(Dictionary dict)
154 {
155     lineSpacing = 20;
156     qsort(dict->rawOutlines, dict->numberOfEntries, sizeof(RawOutlinePair),
157         OrderOutlinePair);
158 }
159
160 #define HIST_SIZE 100
161 void Histogram(int *data, int dataLength, int offset, int *histogram)
162 {

```

```

163     int i,bin;
164     for (i=0;i<dataLength; ++ i) {
165         bin = *data-offset;
166         if ((bin>=0)&&(bin<HIST_SIZE))
167             histogram[bin] ++;
168         data ++;
169     }
170 }
171
172 void HistogramPeaks(int *data,int dataLength, int offset, int *histogram)
173 {
174     int i,bin;
175     Direction direction;
176
177     if (*(data+1) < *data)
178         direction = UP;
179     else {
180         bin = *data-offset;
181         if ((bin>=0)&&(bin<HIST_SIZE))
182             histogram[bin] ++;
183         direction = DOWN;
184     }
185     ++ data;
186
187     for (i=1;i<dataLength-1; ++ i) {
188         if ((direction == UP) &&
189             (*data < *(data+1))) {
190             /* *data is a peak */
191             bin = *data-offset;
192             if ((bin>=0)&&(bin<HIST_SIZE))
193                 histogram[bin] ++;
194             direction = DOWN;
195         }
196         else if ((direction == DOWN) &&
197             (*data > *(data+1))) {
198             /* *data is a valley */
199             direction = UP;
200         }
201         ++ data;
202     } /* for i */
203 }
204
205 void HistogramValleys(int *data,int dataLength, int offset, int *histogram)
206 {
207     int i,bin;
208     Direction direction;
209
210     if (*(data+1) > *data)
211         direction = UP;
212     else {
213         bin = *data-offset;
214         if ((bin>=0)&&(bin<HIST_SIZE))
215             histogram[bin] ++;
216         direction = DOWN;
217     }

```

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```

218     ++data;
219
220     for (i=1;i<dataLength-1;++i) {
221         if ((direction == UP) &&
222             (*data > *(data+1))) {
223             /* *data is a peak */
224             bin = *data-offset;
225             if ((bin>=0)&&(bin<HIST_SIZE))
226                 histogram[bin]++;
227             direction = DOWN;
228         }
229         else if ((direction == DOWN) &&
230                 (*data < *(data+1))) {
231             /* *data is a valley */
232             direction = UP;
233         }
234         ++data;
235     } /* for i */
236 }
237
238 int MaxBin(int *histogram)
239 {
240     int i;
241     int maxValue;
242     int maxIndex;
243
244     maxValue = histogram[0];
245     maxIndex = 0;
246     for (i=0;i<HIST_SIZE;++i)
247         if (histogram[i]>maxValue) {
248             maxValue = histogram[i];
249             maxIndex = i;
250         }
251     return maxIndex;
252 }
253
254 void PostProcess(Dictionary dict)
255 {
256     int index;
257     int temp;
258     int i,startIndex,firstY,minY,endIndex,shape;
259     int tops[HIST_SIZE];
260     int bottoms[HIST_SIZE];
261     int middleLine,topLine,bottomLine;
262     int fontXHeight;
263     RawOutlinePair thisShape;
264
265     SortDictionary(dict);
266
267     index = 0;
268     #ifdef foo
269     malloc_verify();
270     #endif
271     while (index < dict->numberOfEntries) {
272         startIndex = index;

```

```

273 firstY = (*(dict->rawOutlines+index))->box->pageY;
274 minY = firstY;
275 while ( (*(dict->rawOutlines+index))->box->pageY - firstY < 20 &&
276         (*(dict->rawOutlines+index))->box->pageY - firstY > -20) {
277     if ( minY > (*(dict->rawOutlines+index))->box->pageY )
278         minY = (*(dict->rawOutlines+index))->box->pageY;
279     ++index;
280     if (index == dict->numberOfEntries)
281         break;
282 }
283 endIndex = index;
284
285 #ifdef foo
286     malloc_verify();
287 #endif
288
289 /* shapes from start index through endIndex are all on */
290 /* the same text line */
291 /* minY has the top of the highest box on the line. */
292
293 /* Find the base and topline by taking the mode of the heights of the
294 * valleys of the bottom contours and the peaks of the top contours */
295 for (i=0; i<HIST_SIZE; i++) {
296     tops[i]=0;
297     bottoms[i]=0;
298 }
299 for (shape=startIndex; shape<endIndex; ++shape) {
300     thisShape = *(dict->rawOutlines+shape);
301     Histogram(thisShape->top,thisShape->numberOfLegs,minY,tops);
302     Histogram(thisShape->bottom,thisShape->numberOfLegs,minY,bottoms);
303
304 #ifdef foo
305     HistogramPeaks(thisShape->top,thisShape->numberOfLegs,minY,tops);
306     HistogramValleys(thisShape->bottom,thisShape->numberOfLegs,minY,bottoms);
307 #endif
308 }
309 topline = MaxBin(tops)+minY;
310 bottomLine = MaxBin(bottoms)+minY;
311
312 if (thePict) {
313     int maxLength;
314     int halfWidth;
315     int x,y;
316     float x2,x3,y2,y3;
317     float angle;
318
319     angle = (*(dict->rawOutlines))->box->angle;
320     maxLength = thePict->width+thePict->height;
321     halfWidth = thePict->width / 2;
322     x = topline * -sin(angle) + halfWidth * cos(angle);
323     y = topline * cos(angle) + halfWidth * sin(angle);
324     x2 = x+maxLength*cos(angle);
325     y2 = y+maxLength*sin(angle);
326     x3 = x-maxLength*cos(angle);
327     y3 = y-maxLength*sin(angle);

```

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```

328     DrawLine(thePict,x,y,(int)x2,(int)y2,5);
329     DrawLine(thePict,x,y,(int)x3,(int)y3,5);
330
331     x = bottomLine * -sin(angle) + halfWidth * cos(angle);
332     y = bottomLine * cos(angle) + halfWidth * sin(angle);
333     x2 = x + maxLength*cos(angle);
334     y2 = y + maxLength*sin(angle);
335     x3 = x - maxLength*cos(angle);
336     y3 = y - maxLength*sin(angle);
337     DrawLine(thePict,x,y,(int)x2,(int)y2,5);
338     DrawLine(thePict,x,y,(int)x3,(int)y3,5);
339
340 }
341
342 #ifdef foo
343     malloc_verify();
344 #endif
345
346     middleLine = (bottomLine + topLine)/2;
347     fontXHeight = bottomLine - topLine;
348     /* Clip and normalize the contours */
349     for (shape = startIndex; shape < endIndex; ++shape)
350         StoreOutlinePair(dict,shape,middleLine,fontXHeight);
351     } /* Do another line of text */
352 }

```

Jul 1 13:46 1991 postproc.c

```

1  #include <stdio.h>
2  #include <math.h>
3  #include "boolean.h"
4  #include "types.h"
5  #include "error.h"
6  #include "pict.h"
7  #include "dict.h"
8
9  #define UP 0
10 #define DOWN 1
11 typedef int Direction;
12
13 extern Picture thePict;
14
15 void StoreRawOutlinePair(Dictionary dict, int dictEntry,
16                          Box box, int *bothX, int *topY, int *baseY,
17                          int numberOfLegs)
18 {
19     RawOutlinePair temp;
20     int i;
21     int *xCursor, *topCursor, *bottomCursor;
22
23     temp = (RawOutlinePair) calloc(1, sizeof(RawOutlinePairBody));
24     if (temp == NULL)
25         DoError("StoreRawOutlinePair: cannot allocate space\n", NULL);
26
27     temp->box = box;
28     temp->numberOfLegs = numberOfLegs;
29
30     temp->x = (int *) calloc(temp->numberOfLegs, sizeof(int));
31     temp->top = (int *) calloc(temp->numberOfLegs, sizeof(int));
32     temp->bottom = (int *) calloc(temp->numberOfLegs, sizeof(int));
33     if ((temp->x == NULL) ||
34         (temp->top == NULL) ||
35         (temp->bottom == NULL))
36         DoError("StoreRawOutlinePair: cannot allocate space\n", NULL);
37
38     xCursor = temp->x;
39     topCursor = temp->top;
40     bottomCursor = temp->bottom;
41
42     for (i=0; i<numberOfLegs; ++i) {
43         *xCursor++ = *bothX++;
44         *topCursor++ = *topY++;
45         *bottomCursor++ = *baseY++;
46     }
47     *(dict->rawOutlines + dictEntry) = temp;
48 }
49
50 void StoreOutlinePair(Dictionary dict, int dictEntry,
51                       int middleLine, int fontXHeight)
52 {

```



```

53     RawOutlinePair raw;
54     OutlinePair temp;
55     int i,numberOfLegs;
56     int y;
57     int offset;
58     int *xSCursor,*topSCursor,*bottomSCursor;
59     float *xDCursor,*topDCursor,*bottomDCursor;
60     float *xCursor,*topCursor,*bottomCursor;
61     int left,right;
62     float foffset;
63
64     raw = *(dict->rawOutlines+dictEntry);
65
66     temp = (OutlinePair)calloc(1,sizeof(OutlinePairBody));
67     if (temp == NULL)
68         DoError("StoreOutlinePair: cannot allocate space\n",NULL);
69
70     temp->x = (float *)calloc(raw->numberOfLegs,sizeof(float));
71     temp->top = (float *)calloc(raw->numberOfLegs,sizeof(float));
72     temp->bottom = (float *)calloc(raw->numberOfLegs,sizeof(float));
73     if ((temp->x == NULL) ||
74         (temp->top == NULL) ||
75         (temp->bottom == NULL))
76         DoError("StoreOutlinePair: cannot allocate space\n",NULL);
77
78     temp->box = raw->box;
79     temp->blackoutHeight = 0;
80     temp->numberOfLegs = raw->numberOfLegs;
81     offset = temp->offset = *(raw->x);
82     temp->width = *(raw->x+raw->numberOfLegs-1) - temp->offset;
83
84     xDCursor = temp->x;
85     topDCursor = temp->top;
86     bottomDCursor = temp->bottom;
87     xSCursor = raw->x;
88     topSCursor = raw->top;
89     bottomSCursor = raw->bottom;
90
91     numberOfLegs = raw->numberOfLegs;
92     for (i=0;i<numberOfLegs; ++i) {
93         *xDCursor++ = (float)(*xSCursor++ - offset)/fontXHeight;
94         y = middleLine - *topSCursor++;
95         if (y<0)
96             y = 0;
97         *topDCursor++ = (float)y / fontXHeight;
98         y = *bottomSCursor++ - middleLine;
99         if (y<0)
100             y = 0;
101         *bottomDCursor++ = (float)y / fontXHeight;
102     }
103
104     /* Now try to remove parts of the contour on to the left and right of the
105     * word shape that are at height 0 */
106
107     topDCursor = temp->top;

```

```

108     bottomDCursor = temp->bottom;
109     for (i=0; i<numberOfLegs; ++i) {
110         if ((*topDCursor++ != 0) || (*bottomDCursor++ != 0))
111             break;
112     }
113     left = i;
114
115     topDCursor = temp->top + numberOfLegs - 1;
116     bottomDCursor = temp->bottom + numberOfLegs - 1;
117     for (i=numberOfLegs-1; i>=0; --i) {
118         if ((*topDCursor-- != 0) || (*bottomDCursor-- != 0))
119             break;
120     }
121     right = i + 1;
122
123     xDCursor = temp->x;
124     topDCursor = temp->top;
125     bottomDCursor = temp->bottom;
126     xCursor = temp->x + left;
127     topCursor = temp->top + left;
128     bottomCursor = temp->bottom + left;
129     offset = *xSCursor;
130     for (i=left; i<right; ++i) {
131         *xDCursor++ = *xCursor++ - offset;
132         *topDCursor++ = *topCursor++;
133         *bottomDCursor++ = *bottomCursor++;
134     }
135     temp->numberOfLegs = right-left;
136
137     *(dict->outlines + dictEntry) = temp;
138 }
139
140 static int lineSpacing;
141 int OrderOutlinePair(OutlinePair *o1, OutlinePair *o2)
142 {
143     int yDistance;
144     int xDistance;
145     yDistance = (*o1)->box->pageY - (*o2)->box->pageY;
146     if (yDistance < lineSpacing && yDistance > -lineSpacing) {
147         xDistance = (*o1)->box->pageX - (*o2)->box->pageX;
148         return xDistance;
149     }
150     return yDistance;
151 }
152
153 void SortDictionary(Dictionary dict)
154 {
155     lineSpacing = 20;
156     qsort(dict->rawOutlines, dict->numberOfEntries, sizeof(RawOutlinePair),
157         OrderOutlinePair);
158 }
159
160 #define HIST_SIZE 100
161 void HistogramMax(int *data, int dataLength, int offset, int sign, int *histogram)
162 {

```

```

163     int i,bin;
164
165     if (sign>0) {
166         int maxValue;
167         maxValue = *data;
168         for (i=0;i<dataLength; ++ i)
169             if (data[i]>maxValue)
170                 maxValue = data[i];
171         bin = maxValue-offset;
172         if ((bin>=0)&&(bin<HIST_SIZE))
173             histogram[bin] ++;
174     }
175     else {
176         int minValue;
177         minValue = *data;
178         for (i=0;i<dataLength; ++ i)
179             if (data[i]<minValue)
180                 minValue = data[i];
181         bin = minValue-offset;
182         if ((bin>=0)&&(bin<HIST_SIZE))
183             histogram[bin] ++;
184     }
185 }
186
187 void Histogram(int *data,int dataLength,int offset,int *histogram)
188 {
189     int i,bin;
190
191     for (i=0;i<dataLength; ++ i) {
192         bin = *data-offset;
193         if ((bin>=0)&&(bin<HIST_SIZE))
194             histogram[bin] ++;
195         data ++;
196     }
197 }
198
199 void HistogramPeaks(int *data,int dataLength,int offset,int *histogram)
200 {
201     int i,bin;
202     Direction direction;
203
204     if (*(data+1) < *data)
205         direction = UP;
206     else {
207         bin = *data-offset;
208         if ((bin>=0)&&(bin<HIST_SIZE))
209             histogram[bin] ++;
210         direction = DOWN;
211     }
212     ++ data;
213
214     for (i=1;i<dataLength-1; ++ i) {
215         if ((direction == UP) &&
216             (*data < *(data+1))) {
217             /* *data is a peak */

```

```

218     bin = *data-offset;
219     if ((bin>=0)&&(bin<HIST_SIZE))
220         histogram[bin]++;
221     direction = DOWN;
222 }
223 else if ((direction == DOWN) &&
224         (*data > *(data+1))) {
225     /* *data is a valley */
226     direction = UP;
227 }
228 ++data;
229 } /* for i */
230 }
231
232 void HistogramValleys(int *data,int dataLength, int offset, int *histogram)
233 {
234     int i,bin;
235     Direction direction;
236
237     if (*(data+1) > *data)
238         direction = UP;
239     else {
240         bin = *data-offset;
241         if ((bin>=0)&&(bin<HIST_SIZE))
242             histogram[bin]++;
243         direction = DOWN;
244     }
245     ++data;
246
247     for (i=1;i<dataLength-1;++i) {
248         if ((direction == UP) &&
249             (*data > *(data+1))) {
250             /* *data is a peak */
251             bin = *data-offset;
252             if ((bin>=0)&&(bin<HIST_SIZE))
253                 histogram[bin]++;
254             direction = DOWN;
255         }
256         else if ((direction == DOWN) &&
257                 (*data < *(data+1))) {
258             /* *data is a valley */
259             direction = UP;
260         }
261         ++data;
262     } /* for i */
263 }
264
265 int MaxBin(int *histogram)
266 {
267     int i;
268     int maxValue;
269     int maxIndex;
270
271     maxValue = histogram[0];
272     maxIndex = 0;

```

```

273     for (i=0; i<HIST_SIZE; ++i)
274         if (histogram[i]>maxValue) {
275             maxValue = histogram[i];
276             maxIndex = i;
277         }
278     return maxIndex;
279 }
280
281 void PostProcess(Dictionary dict)
282 {
283     int index;
284     int temp;
285     int i, startIndex, firstY, minY, endIndex, shape;
286     int tops[HIST_SIZE];
287     int bottoms[HIST_SIZE];
288     int middleLine, topLine, bottomLine;
289     int fontXHeight;
290     RawOutlinePair thisShape;
291
292     SortDictionary(dict);
293
294     index = 0;
295     #ifdef foo
296     malloc_verify();
297     #endif
298     while (index < dict->numberOfEntries) {
299         startIndex = index;
300         firstY = (*(dict->rawOutlines+index))->box->pageY;
301         minY = firstY;
302         while ((*(dict->rawOutlines+index))->box->pageY - firstY < 20 &&
303             (*(dict->rawOutlines+index))->box->pageY - firstY > -20) {
304             if (minY > (*(dict->rawOutlines+index))->box->pageY)
305                 minY = (*(dict->rawOutlines+index))->box->pageY;
306             ++index;
307             if (index == dict->numberOfEntries)
308                 break;
309         }
310         endIndex = index;
311
312         #ifdef foo
313         malloc_verify();
314         #endif
315
316         /* shapes from start index through endIndex are all on */
317         /* the same text line */
318         /* minY has the top of the highest box on the line. */
319
320         /* Find the base and topline by taking the mode of the heights of the
321          * valleys of the bottom contours and the peaks of the top contours */
322         for (i=0; i<HIST_SIZE; ++i) {
323             tops[i]=0;
324             bottoms[i]=0;
325         }
326         for (shape=startIndex; shape<endIndex; ++shape) {
327             thisShape = *(dict->rawOutlines+shape);

```

```

328     Histogram(thisShape->top,thisShape->numberOfLegs,minY,tops);
329     Histogram(thisShape->bottom,thisShape->numberOfLegs,minY,bottoms);
330
331     #ifdef foo
332         HistogramPeaks(thisShape->top,thisShape->numberOfLegs,minY,tops);
333         HistogramValleys(thisShape->bottom,thisShape->numberOfLegs,minY,bottoms);
334     #endif
335     }
336     topLine = MaxBin(tops)+minY;
337     bottomLine = MaxBin(bottoms)+minY;
338
339     if (thePict) {
340         int maxLength;
341         int halfWidth;
342         int x,y;
343         float x2,x3,y2,y3;
344         float angle;
345
346         angle = (*(dict->rawOutlines))->box->angle;
347         maxLength = thePict->width + thePict->height;
348         halfWidth = thePict->width / 2;
349         x = topLine * -sin(angle) + halfWidth * cos(angle);
350         y = topLine * cos(angle) + halfWidth * sin(angle);
351         x2 = x + maxLength*cos(angle);
352         y2 = y + maxLength*sin(angle);
353         x3 = x - maxLength*cos(angle);
354         y3 = y - maxLength*sin(angle);
355         DrawLine(thePict,x,y,(int)x2,(int)y2,5);
356         DrawLine(thePict,x,y,(int)x3,(int)y3,5);
357
358         x = bottomLine * -sin(angle) + halfWidth * cos(angle);
359         y = bottomLine * cos(angle) + halfWidth * sin(angle);
360         x2 = x + maxLength*cos(angle);
361         y2 = y + maxLength*sin(angle);
362         x3 = x - maxLength*cos(angle);
363         y3 = y - maxLength*sin(angle);
364         DrawLine(thePict,x,y,(int)x2,(int)y2,5);
365         DrawLine(thePict,x,y,(int)x3,(int)y3,5);
366     }
367 }
368
369 #ifdef foo
370     malloc_verify();
371 #endif
372
373     middleLine = (bottomLine + topLine)/2;
374     fontXHeight = bottomLine-topLine;
375     /* Clip and normalize the contours */
376     for (shape=startIndex;shape<endIndex; ++shape)
377         StoreOutlinePair(dict,shape,middleLine,fontXHeight);
378     } /* Do another line of text */
379 }
380
381 void PageStatistics(Dictionary dict,char *fileName)
382 /* WARNING - this must be run before PostProcess since PostProcess changes the raw

```

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```

383  * shape data. */
384  {
385      int index;
386      int temp;
387      int i, startIndex, firstY, minY, endIndex, shape;
388      int tops[HIST_SIZE];
389      int bottoms[HIST_SIZE];
390      int ascenders[HIST_SIZE];
391      int descenders[HIST_SIZE];
392      int middleLine, topLine, bottomLine, ascenderLine, descenderLine;
393      int ascenderHeight, descenderHeight, lineNumber;
394      int fontXHeight;
395      RawOutlinePair thisShape;
396      FILE *fp;
397
398      if ((fp = fopen(fileName, "w")) == NULL)
399          DoError("PageStatistics: error opening output file %s.\n", fileName);
400
401      SortDictionary(dict);
402
403      index = 0;
404      #ifdef foo
405          malloc_verify();
406      #endif
407      lineNumber = 0;
408      while (index < dict->numberOfEntries) {
409          startIndex = index;
410          firstY = (*(dict->rawOutlines + index))->box->pageY;
411          minY = firstY;
412          while ((*(dict->rawOutlines + index))->box->pageY - firstY < 20 &&
413              (*(dict->rawOutlines + index))->box->pageY - firstY > -20) {
414              if (minY > (*(dict->rawOutlines + index))->box->pageY)
415                  minY = (*(dict->rawOutlines + index))->box->pageY;
416              ++index;
417              if (index == dict->numberOfEntries)
418                  break;
419          }
420          endIndex = index;
421
422      #ifdef foo
423          malloc_verify();
424      #endif
425
426      /* shapes from start index through endIndex are all on */
427      /* the same text line */
428      /* minY has the top of the highest box on the line. */
429
430      /* Find the base and topline by taking the mode of the heights of the
431      * valleys of the bottom contours and the peaks of the top contours */
432      for (i = 0; i < HIST_SIZE; i++) {
433          tops[i] = 0;
434          bottoms[i] = 0;
435          ascenders[i] = 0;
436          descenders[i] = 0;
437      }

```

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```

438     for (shape=startIndex;shape<endIndex; ++ shape) {
439         thisShape = *(dict->rawOutlines+ shape);
440         Histogram(thisShape-> top,thisShape-> numberOfLegs,minY,tops);
441         Histogram(thisShape-> bottom,thisShape-> numberOfLegs,minY,bottoms);
442
443         HistogramMax(thisShape-> top,thisShape-> numberOfLegs,minY,-1,ascenders);
444         HistogramMax(thisShape-> bottom,thisShape-> numberOfLegs,minY,1,descenders);
445     }
446     topLine = MaxBin(tops)+ minY;
447     bottomLine = MaxBin(bottoms)+ minY;
448     ascenderLine = MaxBin(ascenders)+ minY;
449     descenderLine = MaxBin(descenders)+ minY;
450
451     #ifdef foo
452         malloc_verify();
453     #endif
454
455     middleLine = (bottomLine+ topLine)/2;
456     fontXHeight = bottomLine-topLine;
457
458     ascenderHeight = bottomLine-ascenderLine;
459     descenderHeight = descenderLine-bottomLine;
460     fprintf(fp,"%d: %d %d %d
%2.6f\n",lineNumber,fontXHeight,ascenderHeight,descenderHeight,
461         (float)ascenderHeight/(float)fontXHeight);
462     ++ lineNumber;
463 } /* Do another line of text */
464 fclose(fp);
465 }

```


Jul 10 13:17 1991 testFine.c

```

1  #include <stdio.h>
2  #include <math.h>
3  #include "boolean.h"
4  #include "pict.h"
5  #include "lines.h"
6
7  #define ABS(x) (((x)<0)?(-(x)):(x))
8
9  extern long random();
10
11 int RandomCoordinate(int maxValue)
12 {
13     return (float)(random()&0xffff)*maxValue/0xffff;
14 }
15
16 void RandomEdgePixel(Picture pict,int *x, int *y)
17 {
18     while (TRUE) {
19         *x = RandomCoordinate(pict->width);
20         *y = RandomCoordinate(pict->height);
21         if (ReadPixel(pict,*x,*y))
22             if (!(ReadPixel(pict,*x+1,*y) &&
23                 ReadPixel(pict,*x-1,*y) &&
24                 ReadPixel(pict,*x,*y+1) &&
25                 ReadPixel(pict,*x,*y-1) &&
26                 ReadPixel(pict,*x+1,*y+1) &&
27                 ReadPixel(pict,*x-1,*y-1) &&
28                 ReadPixel(pict,*x+1,*y-1) &&
29                 ReadPixel(pict,*x-1,*y+1)))
30                 return;
31     }
32 }
33
34
35 float Fine(Picture pict,int fineSamples, int fineDirections,
36           float angleStart,float angleEnd, char *plotFile)
37 {
38     int x,y;
39     float x2,y2;
40     int i,j;
41     float *counters;
42     float step,angle;
43     float maxAngle;
44     float maxValue;
45     float maxLength;
46     FILE *outfile;
47
48     counters = (float *)calloc(fineDirections,sizeof(float));
49     if (counters == NULL) {
50         printf("Fine: cannot allocate memory\n");
51         exit(-1);
52     }

```

```

53
54     step = ABS(angleEnd - angleStart)/fineDirections;
55
56     maxLength = sqrt((double)(pict->width*pict->width+
57                             pict->height*pict->height));
58     for (i=0;i<fineSamples; ++i) {
59         RandomEdgePixel(pict,&x,&y);
60         angle = angleStart;
61         for (j=0;j<fineDirections; ++j) {
62             angle = fmod(angle,2*M_PI);
63             x2 = x + maxLength*cos(angle);
64             y2 = y + maxLength*sin(angle);
65             counters[j] += CountLine(pict,x,y,(int)x2,(int)y2);
66             angle += step;
67         }
68     }
69
70     angle = angleStart;
71     maxAngle = angle;
72     maxValue = counters[0];
73     for (i=0;i<fineDirections; ++i) {
74         angle = fmod(angle,2*M_PI);
75         if (counters[i]>maxValue) {
76             maxAngle = angle;
77             maxValue = counters[i];
78         }
79         angle += step;
80     }
81     printf("Orientation is at %f(%%f)\n",maxAngle,maxAngle/2/M_PI*360);
82
83     /* Plot the orientation graph if requested */
84     printf("Opening fine orientation plot file\n");
85     if ((outfile = fopen(plotFile,"w")) == NULL) {
86         printf("Error opening fine orientation plot file.\n");
87         exit(-1);
88     }
89     angle = angleStart;
90     for (i=0;i<fineDirections; ++i) {
91         angle = fmod(angle,2*M_PI);
92         fprintf(outfile,"%f %%f\n",angle,counters[i]);
93         angle += step;
94     }
95     fprintf(outfile,"\n\"Fine Distances\n\n");
96     fclose(outfile);
97     printf("Done writing fine orientation plot file.\n");
98     return maxAngle;
99 }
100
101 main(argc, argv)
102 int argc;
103 char *argv[];
104 {
105     char *inFileName,*coarseOutFileName,*fineOutFileName,*fine2OutFileName;
106     int fineDirections,fineSamples;
107     float coarseAngle,fineAngle,fineAngle2;

```

Section D

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```

108 float firstSpacing,secondSpacing,thirdSpacing;
109 Picture pict;
110
111 if (argc != 7)
112 {
113     printf("\nUsage: %s Infile coarsePlotFile finePlotFile\n",argv[0]);
114     printf("    finerPlotFile #directions #samples\n\n");
115
116     exit(0);
117 }
118
119 inFileName = argv[1]; /* get args */
120 coarseOutFileName = argv[2];
121 fineOutFileName = argv[3];
122 fine2OutFileName = argv[4];
123 fineDirections = atoi(argv[5]);
124 fineSamples = atoi(argv[6]);
125
126 pict = load_pict(inFileName);
127 coarseAngle = Fine(pict,fineSamples,fineDirections,
128     0,M_PI,coarseOutFileName);
129 firstSpacing = (M_PI-0)/fineDirections;
130 printf("Coarse angle: %f(%f)\n",coarseAngle,coarseAngle/M_PI*180);
131 printf("Coarse spacing: %f(%f)\n",firstSpacing,firstSpacing/M_PI*180);
132
133 fineAngle = Fine(pict,fineSamples,fineDirections,
134     coarseAngle-4*firstSpacing,coarseAngle+4*firstSpacing,
135     fineOutFileName);
136 secondSpacing = 8*firstSpacing/fineDirections;
137 printf("Fine angle: %f(%f)\n",fineAngle,fineAngle/M_PI*180);
138 printf("Fine spacing: %f(%f)\n",secondSpacing,secondSpacing/M_PI*180);
139
140 fineAngle2 = Fine(pict,fineSamples,fineDirections,
141     fineAngle-15*secondSpacing,fineAngle+15*secondSpacing,
142     fine2OutFileName);
143 thirdSpacing = 30*secondSpacing/fineDirections;
144 printf("Finer angle: %f(%f)\n",fineAngle2,fineAngle2/M_PI*180);
145 printf("Finer spacing: %f(%f)\n",thirdSpacing,thirdSpacing/M_PI*180);
146 }
147

```

Section D

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```
1  #include "stdio.h"
2  #include "mylib.h"
3  #include "types.h"
4  #include "error.h"
5
6  Box MakeBox(int x,int y,int width,int height,double angle)
7  {
8      Box temp;
9      temp = (Box)calloc(1,sizeof(BoxBody));
10     if (temp == NULL)
11         DoError("MakeBox: out of memory\n",NULL);
12     temp->x = x;
13     temp->y = y;
14     temp->width = width;
15     temp->height = height;
16     temp->angle = angle;
17     return temp;
18 }
19
20 Point MakePoint(int x,int y)
21 {
22     Point temp;
23     temp = (Point)calloc(1,sizeof(PointBody));
24     if (temp == NULL)
25         DoError("MakePoint: out of memory\n",NULL);
26     temp->x = x;
27     temp->y = y;
28     return temp;
29 }
30
31
32
```

We claim:

1. A method for electronically processing an electronic document image without first decoding the electronic document image, comprising:

segmenting the document image into word image units without decoding the document image;

deriving a word shape representation for each of a plurality of said word image units without decoding any characters making up the plurality of word image units, thereby deriving a plurality of said word shape representations;

comparing said word shape representations to at least one other word shape representation to identify significant word image units from amongst said plurality of word image units; and

creating an abbreviated document image that is smaller than the electronic document image based on said identified significant word image units, said abbreviated document image including a plurality of said identified significant word image units.

2. The method of claim 1 wherein said step of comparing includes classifying said word image units according to frequency of occurrence based on comparing said word shape representations with each other.

3. The method of claim 1 wherein said step of comparing includes classifying said word image units according to location within the document image.

4. The method of claim 1 wherein said step of deriving a word shape representation includes utilization of at least one of an image unit shape dimension, font, typeface, number of ascender elements, number of descender elements, pixel density, pixel cross-sectional characteristic, the location of word image units with respect to neighboring word image units, vertical position, horizontal interimage unit spacing, and contour characteristic of said word image units.

5. The method of claim 1, wherein said comparing step includes comparing said word shape representations with each other.

6. The method of claim 1, wherein said comparing step includes comparing said word shape representations with at least one predetermined word shape representation.

7. The method of claim 1, wherein said comparing step includes comparing said word shape representations with at least one user-selected word shape representation.

8. A method of excerpting significant information from an undecoded document image without decoding the document image, comprising:

segmenting the document image into word image units without decoding the document image;

deriving a word shape representation for each of a plurality of said word image units without decoding any characters making up said plurality of word image units, thereby deriving a plurality of said word shape representations;

comparing said word shape representations to at least one other word shape representation to identify significant word image units from amongst said word image units; and

outputting a plurality of said identified significant word image units for further processing.

9. The method of claim 8 wherein said step of outputting a plurality of identified significant image units comprises generating a document index based on said significant identified word image units.

10. The method of claim 8 wherein said step of outputting a plurality of identified significant image units comprises producing a speech synthesized output corresponding to said identified significant word image units.

11. The method of claim 8 wherein said step of outputting a plurality of identified significant word image units comprises producing said identified significant word image units in printed Braille format.

12. The method of claim 8 wherein said step of outputting said a plurality of identified significant word image units comprises generating a document summary from said identified significant word image units.

13. A method for electronically processing an undecoded document image containing word text, comprising:

segmenting the document image into word image units without decoding the document image;

deriving a word shape representation for each of a plurality of said word image units without decoding any characters making up said plurality of word image units, thereby deriving a plurality of said word shape representations;

comparing said word shape representations to at least one other word shape representation to identify significant word image units from amongst said plurality of word image units;

forming phrase image units based on a plurality of said identified significant word image units, said phrase image units each incorporating one of said identified significant word image units and adjacent word image units linked in reading order sequence; and

outputting said phrase image units.

14. An apparatus for automatically summarizing the information content of an undecoded document image without decoding the document image, comprising:

means for segmenting the document image into word image units without decoding the document image;

means for deriving a word shape representation for each of a plurality of said word image units without decoding any characters making up said plurality of word image units, thereby deriving a plurality of said word shape representations;

means for comparing said word shape representations to at least one other word shade representation to identify significant word image units from amongst said plurality of word image units; and

means for creating a supplemental document image based on said identified significant word image units.

15. The apparatus of claim 14 wherein said means for segmenting the document image, said means for deriving a word shape representation, said means for comparing, said means for creating a supplemental document image comprise a programmed digital computer.

16. The apparatus of claim 15 further comprising scanning means for scanning an original document to produce said document image, said scanning means being incorporated in a document copier machine which produces printed

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document copies; and means for controlling said document copier machine to produce a printed document copy of said supplemental document image.

17. The apparatus of claim 15 further comprising scanning means for scanning an original document to produce said document image, said scanning means being incorporated in a reading machine for the blind having means for communicating data to the user; and means for controlling said reading machine communication means to communicate the contents of said supplemental document image.

18. The apparatus of claim 17 wherein said communicating means comprises a printer for producing document copies in Braille format.

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19. The apparatus of claim 17 wherein said communicating means comprises a speech synthesizer for producing synthesized speech output corresponding to said supplemental document image.

20. The apparatus of claim 17 wherein said reading machine includes operator responsive means for accessing the scanned document or a selected portion thereof corresponding to a supplemental document image following communication of the supplemental document image to the user.

* * * * *